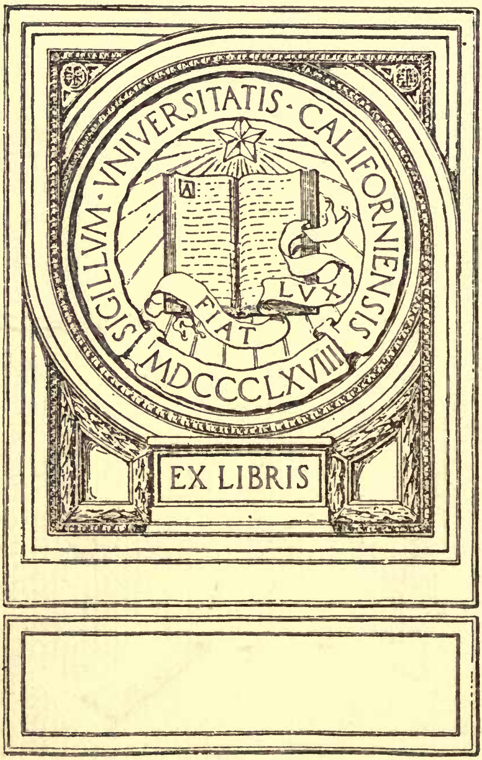
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A MANUAL

OF

ENGINEERING DRAWING

FOR

(STUDENTS AND DRAFTSMEN)

BY

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PREFACE

There is a wide diversity of method in the teaching of engineering drawing, and perhaps less uniformity in the courses in different schools than would be found in most subjects taught in technical schools and colleges. In some well-known instances the attempt is made to teach the subject by giving a series of plates to be copied by the student. Some give all the time to laboratory work, others depend principally upon recitations and home work. Some begin immediately on the theory of descriptive geometry, working in all the angles, others discard theory and commence with a course in machine detailing. Some advocate the extensive use of models, some condemn their use entirely.

Different courses have been designed for different purposes, and criticism is not intended, but it would seem that better unity of method might result if there were a better recognition of the conception that drawing is a real language, to be studied and taught in the same way as any other language. With this conception it may be seen that except for the practice in the handling and use of instruments, and for showing certain standards of execution, copying drawings does little more in the study as an art of expression of thought than copying paragraphs from a German book would do in beginning the study of the German language.

And it would appear equally true that good pedagogy would not advise taking up composition in a new language before the simple structure of the sentence is understood and appreciated; that is, "working drawings" would not be considered until after the theory of projection has been explained.

After a knowledge of the technic of expression, the "penmanship and orthography," the whole energy should be directed toward training in constructive imagination, the perceptive ability which enables one to think in three dimensions, to visualize quickly and accurately, to build up a clear mental image, a requirement absolutely necessary for the designer who is to represent his thoughts on paper. That this may be accomplished more readily by taking up solids before points and lines has been demonstrated beyond dispute.

It is then upon this plan, regarding drawing as a language, the universal graphical language of the industrial world, with its varied forms of expression, its grammar and its style, that this book has been built. It is not a "course in drawing," but a text-book, with exercises and problems in some variety from which selections may be made.

Machine parts furnish the best illustrations of principles, and have been used freely, but the book is intended for all engineering students. Chapters on architectural drawing and map drawing have been added, as in the interrelation of the professions every engineer should be able to read and work from such drawings.

In teaching the subject, part of the time, at least one hour per week, may profitably be scheduled for class lectures, recitations, and blackboard work, at which time there may be distributed "study sheets" or home plates, of problems on the assigned lesson, to be drawn in pencil and returned at the next corresponding period. In the drawing-room period, specifications for plates, to be approved in pencil and some finished by inking or tracing, should be assigned, all to be done under the careful supervision of the instructor.

The judicious use of models is of great aid, both in technical sketching and, particularly, in drawing to scale, in aiding the student to feel the sense of proportion between the drawing and the structure, so that in reading a drawing he may have the ability to visualize not only the shape, but the size of the object represented.

In beginning drawing it is not advisable to use large plates. One set of commercial drafting-room sizes is based on the division of a 36″x48″ sheet into 24″x36″, 18″x24″, 12″x18″ and 9″x12″. The size 12″x18″ is sufficiently large for first year work, while 9″x12″ is not too small for earlier plates.

Grateful acknowledgement is made of the assistance of Messrs. Robert Meiklejohn, O. E. Williams, A. C. Harper, Cree Sheets, F. W. Ives, W. D. Turnbull, and W. J. Norris of the staff of the Department of Engineering Drawing, Ohio State University, not

only in the preparation of the drawings, but in advice and suggestion on the text. Other members of the faculty of this University have aided by helpful criticism.

The aim has been to conform to modern engineering practice, and it is hoped that the practical consideration of the draftsman's needs will give the book permanent value as a reference book in the student's library.

The author will be glad to co-operate with teachers using it as a text-book.

COLUMBUS, OHIO.
May 6, 1911.

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ENGINEERING DRAWING

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CHAPTER I.

INTRODUCTORY.

By the term Engineering Drawing is meant drawing as used in the industrial world by engineers and designers, as the language in which is expressed and recorded the ideas and information necessary for the building of machines and structures; as distinguished from drawing as a fine art, as practised by artists in pictorial representation.

The artist strives to produce, either from the model or landscape before him, or through his creative imagination, a picture which will impart to the observer something as nearly as may be of the same mental impression as that produced by the object itself, or as that in the artist's mind. As there are no lines in nature, if he is limited in his medium to lines instead of color and light and shade, he is able only to suggest his meaning, and must depend upon the observer's imagination to supply the lack.

The engineering draftsman has a greater task. Limited to outline alone, he may not simply suggest his meaning, but must give exact and positive information regarding every detail of the machine or structure existing in his imagination. Thus drawing to him is more than pictorial representation; it is a complete graphical language, by whose aid he may describe minutely every operation necessary, and may keep a complete record of the work for duplication or repairs.

In the artist's case the result can be understood, in greater or less degree, by any one. The draftsman's result does not show the object as it would appear to the eye when finished, consequently his drawing can be read and understood only by one trained in the language.

Thus as the foundation upon which all designing is based, engineering drawing becomes, with perhaps the exception of mathematics, the most important single branch of study in a technical school.

When this language is written exactly and accurately, it is done with the aid of mathematical instruments, and is called **mechanical drawing.*** When done with the unaided hand, without the assistance of instruments or appliances, it is known as freehand drawing, or **technical sketching.** Training in both these methods is necessary for the engineer, the first to develop accuracy of measurement and manual dexterity, the second to train in comprehensive observation, and to give control and mastery of form and proportion.

Our object then is to study this language so that we may write it, express ourselves clearly to one familiar with it, and may read it readily when written by another. To do this we must know the alphabet, the grammar and the composition, and be familiar with the idioms, the accepted conventions and the abbreviations.

This new language is entirely a graphical or written one. It cannot be read aloud, but is interpreted by forming a mental picture of the subject represented; and the student's success in it will be indicated not alone by his skill in execution, but by his ability to interpret his impressions, to visualize clearly in space.

It is not a language to be learned only by a comparatively few draftsmen, who will be professional writers of it, but should be understood by all connected with or interested in technical industries, and the training its study gives in quick, accurate observation, and the power of reading description from lines, is of a value quite unappreciated by those not familiar with it.

In this study we must first of all become familiar with the technic of expression, and as instruments are used for accurate work, the first requirement is the ability to use these instruments correctly. With continued practice will come a facility in their use which will free the mind from any thought of the means of expression.

* The term "Mechanical Drawing" is often applied to all constructive graphics, and, although an unfortunate misnomer, has the sanction of long usage.

A knowledge of geometry is desirable as there will be frequent applications of geometrical principles.

We recommend therefore, as preliminary, the drawing of one or two practice plates, and a few of the geometrical figures of Chapter IV which are often referred to, before the mind is occupied with the real principles or "grammar" of the language.

CHAPTER II.

The Selection of Instruments.

In the selection of instruments and material for drawing the only general advice that can be given is to secure the best that can be afforded. For one who expects to do work of professional grade it is a great mistake to buy inferior instruments. Sometimes a beginner is tempted by the suggestion to get cheap instruments for learning, with the expectation of getting better ones later. With reasonable care a set of good instruments will last a lifetime, while poor ones will be an annoyance from the start, and will be worthless after short usage. As good and poor instruments look so much alike that an amateur is unable to distinguish them it is well to have the advice of a competent judge, or to buy only from a trustworthy and experienced dealer.

This chapter will be devoted to a short description of the instruments usually necessary for drawing, and mention of some not in every-day use, but which are of convenience for special work. In this connection, valuable suggestions may be found in the catalogues of the large instrument houses, notably Theo. Alteneder & Sons, Philadelphia; the Keuffel & Esser Co., New York, and the Eugene Dietzgen Co., Chicago. With the exception of the Alteneder instruments, all drawing instruments are made abroad, principally in Germany. Scales, T-squares, surveying instruments, etc., are, however, made in this country.

The following list includes the necessary instruments and materials for ordinary line drawing. The items are numbered for convenience in reference and assignment.

List of Instruments and Materials.

1. Set of drawing instruments, in case or chamois roll, including at least: 5 1/2 in. compass, with fixed needle-point leg, pencil, pen, and lengthening bar.
   5-in. hairspring dividers.
   Two ruling pens.
   Three bow instruments.
   Box of hard leads.

2. Drawing board.
3. T-square.
4. 45° and 30°–60° triangles.
5. 12-in. architects' scale (two flat or one triangular).
6. One doz. thumb tacks.
7. One 6 H and one 2 H drawing pencil.
8. Pencil pointer.
9. Bottle of drawing ink.
10. Penholder, assorted writing pens, and penwiper.
11. French curves.
12. Pencil eraser.
13. Drawing paper, to suit.

To these may added:

14. Cleaning rubber.
15. Hard Arkansas oil stone.
16. Protractor.
17. Bottle holder.
18. Piece of soapstone.
19. 2-ft. or 4-ft. rule..
20. Sketch book.
21. Erasing shield.
22. Dusting cloth.
23. Lettering triangle.

The student should mark all his instruments and materials plainly with initials or name, as soon as purchased and approved.

(1) All modern high-grade instruments are made with some form of "pivot joint," originally invented by Theodore Alteneder in 1850 and again patented in 1871. Before this time, and by

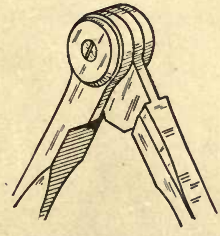


Fig. 1.—Tongue joint.

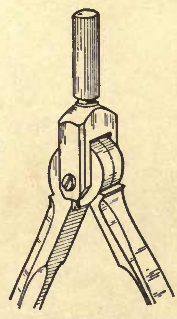


Fig. 2.—Pivot joint (Alteneder).

other makers during the life of the patent, the heads of compasses and dividers were made with tongue joints, as illustrated in Fig. 1, and many of these old instruments are still in existence.

A modified form of this pin joint is still used for some of the cheap grades of instruments. The objection which led to the abandonment of this form was that the wear of the tongue on the pin gave a lost motion, which may be detected by holding a leg in each hand and moving them slowly back and forth. This

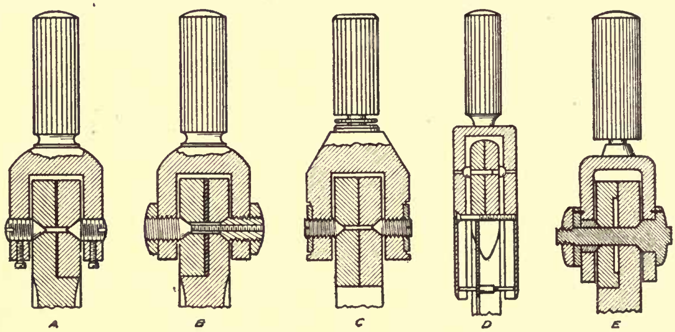


FIG. 3.—Sections of pivot joints.

jump or lost motion after a time increases to such an extent as to render the instrument unfit for use. The pivot joint, Fig. 2, overcomes this objection by putting the wear on the conical points instead of the through pin.

Since the expiration of the patent all instrument makers have adopted this type of head, and several modifications of the

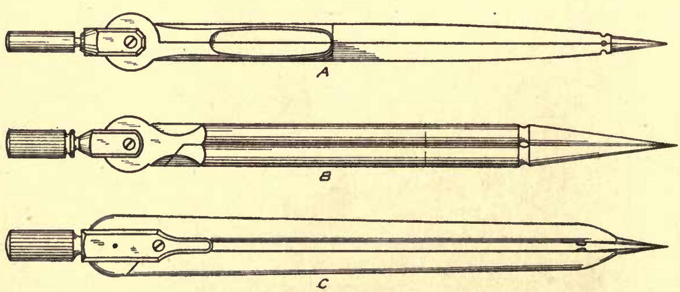


FIG. 4.—The three patterns.

original have been introduced. Sectional views of the different pivot joints are shown in Fig. 3.

The handle attached to the yoke while not essential to the working of the joint is of great convenience. Not all instruments with handles, however, are pivot-joint instruments. Several straightener devices for keeping the handle erect have been devised, but as they interfere somewhat with the smooth working of the joint, they are not regarded with favor by experienced draftsmen.

There are three different patterns or shapes in which modern compasses are made; the regular, the cylindrical and the Richter, Fig. 4. The choice of shapes is entirely a matter of personal preference. After one has become accustomed to the balance

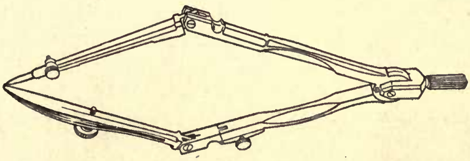


FIG. 5.—Test for alignment.

and feel of a certain instrument he will not wish to exchange it for another shape.

A favorite instrument with draftsmen, not included in the usual college assortment, is the 3 1/2-inch compass with fixed pencil point, and its companion with fixed pen point.

Compasses may be tested for accuracy by bending the knuckle joints and bringing the points together as illustrated in Fig. 5. If out of alignment they should not be accepted.

Dividers are made either "plain," as those in Fig. 4, or "hairspring," shown in Fig. 6. The latter form, which has one leg with screw adjustment, is occasionally of great convenience and

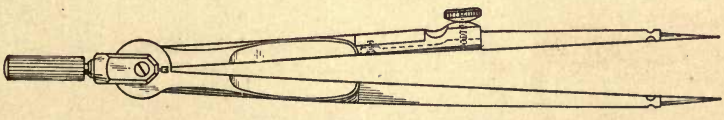


FIG. 6.—Hairspring dividers.

should be preferred. Compasses may be had also with hairspring attachment on the needle-point leg.

Ruling pens (sometimes called right line pens) are made in a variety of forms. An old type has the upper blade hinged for convenience in cleaning. It is open to the serious objection that wear in the joint will throw the nib out of position, and the only remedy will be to solder the joint fast. The improved form has a spring blade opening sufficiently wide to allow of cleaning, Fig. 7. A number are made for resetting after cleaning. Several of these are illustrated in Fig. 8. The form shown at (e) is known as a detail pen or Swede pen. For large work this is a very desirable instrument. Ivory or bone handles break easily and on this account should not be purchased. The nibs of the

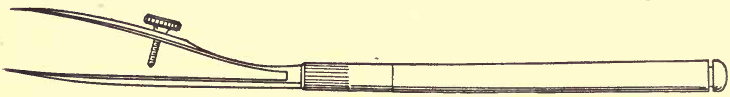


FIG. 7.—Ruling pen, with spring blade.

pen should be shaped as shown in Fig. 434. Cheap pens often come from the factory with points too sharp for use, and must be dressed, as described on page 257, before they can be used.

The set of three spring bow instruments includes bow points or spacers, bow pencil, and bow pen. There are two designs and several sizes. The standard shape is illustrated in Fig. 9, the

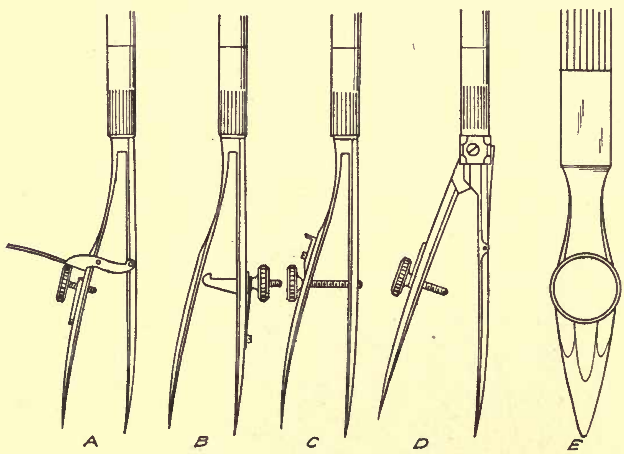


FIG. 8.—Various pens.

hook spring bow in Fig. 10. Both these styles are made with a center screw, Fig. 11, but this form has not become popular among draftsmen. The springs of the side screw bows should be strong enough to open to the length of the screw, but not so stiff as to be difficult to pinch together. The hook spring bow has a softer spring than the regular.

(2) Drawing boards are made of clear white pine (bass wood has been used as a substitute) cleated to prevent warping. Care should be taken in their selection. In drafting-rooms

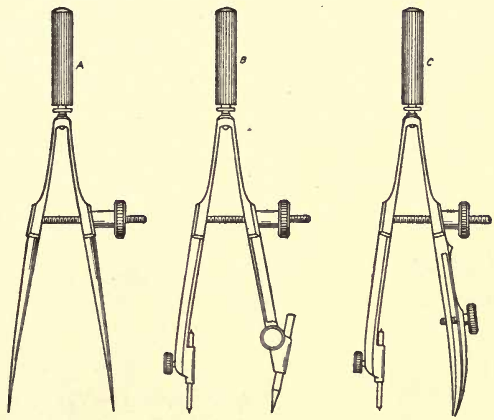


Fig. 9.—Spring bow instruments.

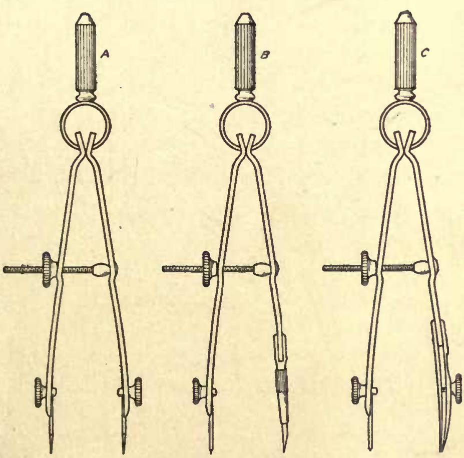


Fig. 10.—Hook-spring bow instruments.

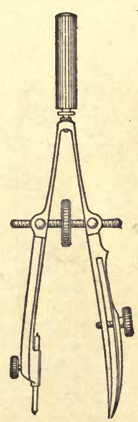


Fig. 11.—Center screw bow.

drawing tables with pine tops are generally used instead of loose boards.

(3) The T-square with fixed head, Fig. 12, is used for all ordinary work. It should be of hard wood, the blade perfectly straight, although it is not necessary that the head be absolutely

square with the blade. In a long square it is preferable to have the head shaped as at B. Fig. 13 is the English type, which is objectionable in that the lower edge is apt to disturb the eyes' sense of perpendicularity. In an office equipment there should always be one or more adjustable head squares, Fig. 14. The

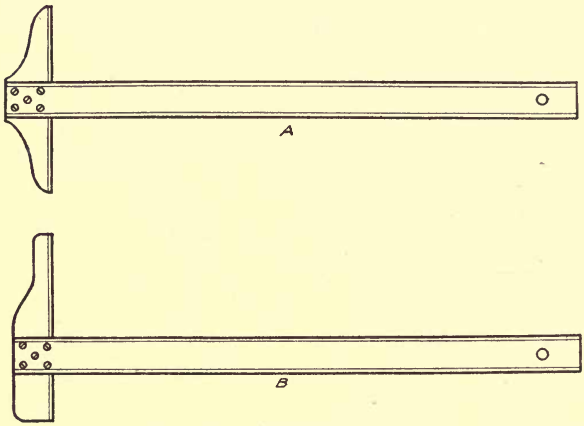


FIG. 12.—Fixed head T-squares.

T-square blade may be tested for straightness by drawing a sharp line with it, then reversing the square.

(4) Triangles (sometimes called set squares) are made of pear wood or cherry, mahogany with ebony edges, hard rubber, and transparent celluloid. The latter are much to be preferred for

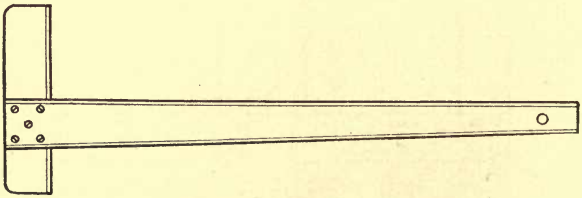


FIG. 13.—English T-square.

a variety of reasons, although they have a tendency to warp. Wooden triangles cannot be depended upon for accuracy, and hard rubber should not be tolerated. For ordinary work a 6″- or 8″-45 degree and a 10″-60 degree are good sizes. A small triangle, 67 1/2 degrees to 70 degrees, will be of value for drawing guide lines in slant lettering. Triangles may be tested for accuracy by drawing perpendicular lines as shown in Fig. 15. The angles may be proven by constructing 45- and 60-degree angles geometrically.

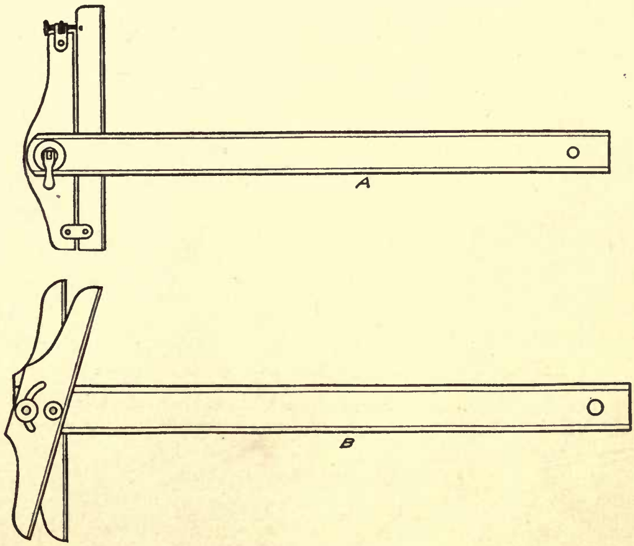


FIG. 14.—Adjustable head T-squares.

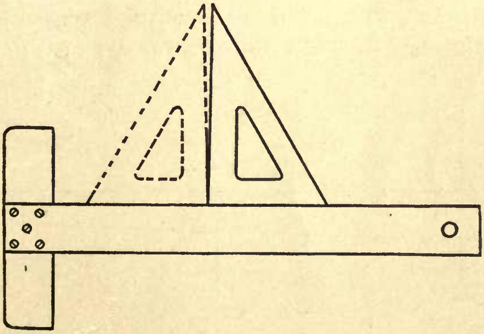


FIG. 15.—To test a triangle.

(5) **Scales.**

There are two kinds of modern scales, the "engineers' scale" of decimal parts, Fig. 16, and the "architects' scale" of proportional feet and inches, Fig. 17. The former is used for plotting and map drawing, and in the graphic solution of problems, the latter for all machine and structural drawings. Scales are usually made of boxwood, sometimes of metal or paper, and of shapes shown in section in Fig. 18. The triangular form (a) is perhaps the commonest. Its only advantage is that it has more

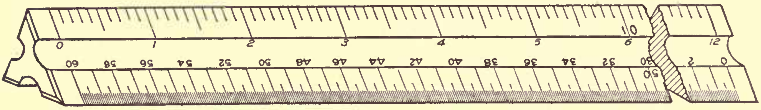


FIG. 16.—Engineers' scale.

scales on one stick than the others, but this is offset by the delay in finding the scale wanted. Flat scales are much more convenient, and should be chosen on this account. Three flat scales are the equivalent of one triangular scale. The "opposite bevel" scale (e) is easier to pick up than the regular form (d). Many

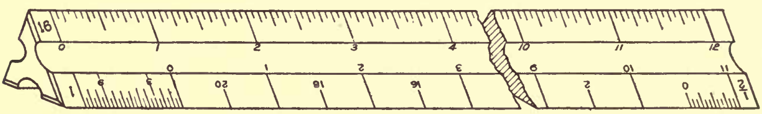


FIG. 17.—Architects' scale.

professional draftsmen use a set of 6 or 8 scales, each graduated in one division only, as Fig. 19.

For the student two 12″ flat scales, one graduated in inches and sixteenths, and 3″ and 1 1/2″, the other 1″, 1/2″, 1/4″, 1/8″, will serve for all ordinary work. The usual triangular scale

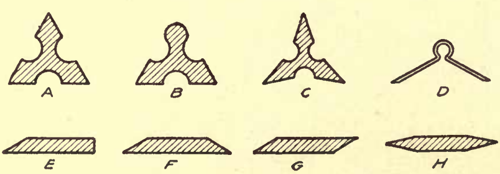


FIG. 18.

contains in addition to these, 3/4″, 3/8″, 3/16″ and 3/32″, and third flat scale with these divisions may be added when needed.

(6) The best thumb tacks are made with thin German silver head and steel point screwed into it (a) Fig. 20, and cost as high as seventy-five cents a dozen. The ordinary stamped tacks (b)

thirty cents a hundred answer every purpose. Tacks with comparatively short, tapering pins should be chosen. Instead of thumb tacks many draftsmen prefer 1/2- or 1-oz. copper tacks, but they are not recommended for students' use.

(7) Drawing pencils are graded by letters from 6B (very soft and black) 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, to 8H (extremely hard). For line work 6H is generally used. A softer pencil (2H) should be used for lettering, sketching and

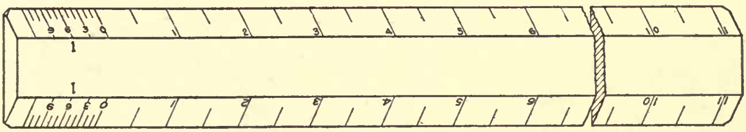


FIG. 19.—Single scale from a set.

penciling not to be inked. Koh-i-noor or Faber are recommended. Many prefer a holder known as an "artists' pencil."

(8) A sandpaper pencil pointer or flat file should always be at hand for sharpening the leads.

(9) Drawing ink is finely ground carbon in suspension, with shellac added to render it waterproof. The non-waterproof ink flows more freely, but smudges very easily.

Formerly all good drawings were made with stick ink, rubbed up for use with water in a slate slab, and for very fine line work this is still preferred as being superior to liquid ink. When

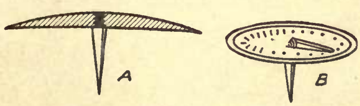


FIG. 20.

used in warm weather a few drops of acetic acid or oxgall should be added to prevent flies from eating it. A fly can eat up a line made of good Chinese ink as fast as it leaves the pen.

(10) The penholder should have a cork grip small enough to enter the mouth of ink bottle. An assortment of pens for lettering, grading from coarse to fine may be chosen from the following:

(Coarse) Leonardt's ball points 506 F, 516 F, 516 EF, or Gillott 1032, 1087, Spencerian No. 21, Esterbrook 788, 802, 805.

(Medium) Spencerian No. 1, Gillott 604, 1050.

(Fine) Gillott No. 1, 303, 170.

(Very fine) For mapping and similar work, Gillott 431, 290, 291 and tit quill.

A penwiper of lintless cloth or thin chamois skin should always be at hand for both writing and ruling pens.

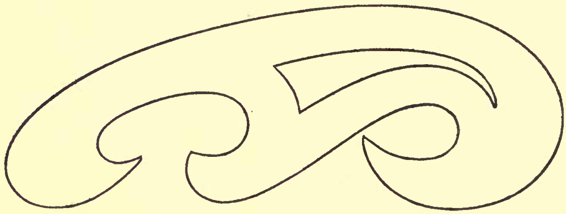


FIG. 21.—Curve.

(11) Curved rulers, called irregular curves, or French curves, are used for curved lines other than circle arcs. Celluloid is the only material to be considered. The patterns for these curves are laid out in parts of ellipses and spirals or other mathematical curves in combinations which will give the closest approximation to curves likely to be met with in practice. For the student, one ellipse curve, of the general shape of Fig. 21, and one spiral,

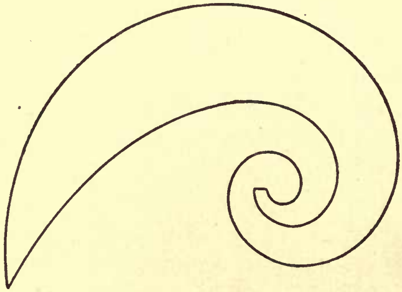


FIG. 22.—Logarithmic spiral curve.

either a log. spiral, Fig. 22, or one similar to the one used in Fig. 65, will be sufficient. It has been found by experiments that the curve of the logarithmic spiral is a closer approximation to the cycloid and other mathematical curves than any other simple curve.

Sometimes it is advisable for the draftsman to make his own templet for special or recurring curves. These may be cut out of thin holly or bass wood, sheet lead, celluloid, or even cardboard or pressboard.

Flexible curved rulers of different kinds are sold. A copper wire or piece of wire solder has been used as a home-made substitute.

The curve illustrated in Fig. 23 has been found particularly useful for engineering diagrams, steam curves, etc. It is plotted on the polar equation $r = A \cos \theta + K$, in which A may be about 5 1/2″ and K 8″.

(12) The ruby pencil eraser is the favorite at present. One of large size, with beveled end is preferred. This eraser is much

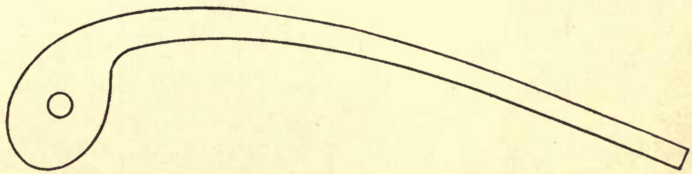


FIG. 23.

better for ink than a so-called ink eraser, as it will remove the ink perfectly without destroying the surface of paper or cloth. A piece of soft "H" rubber, or sponge rubber is useful for cleaning paper.

(13) Drawing paper is made in a variety of qualities, white for finished drawings and cream or buff tint for detail drawings. It may be had either in sheets or rolls. In general, paper should have sufficient grain to "tooth" to take the pencil, be agreeable to the eye, and have good erasing qualities. In white paper the brands known as "Normal" and "Napoleon" have these qualities. For wash drawings Whatman's paper should be used, and for fine line work for reproduction Reynold's Bristol board. These are both English papers in sheets, whose sizes may be found listed in any dealer's catalogue. Whatman's is a hand-made paper in three finishes, H, C.P., and R, or hot pressed, cold pressed, and rough; the first for fine line drawings, the second for either ink or color, and the third for water color sketches. The paper in the larger sheets is heavier than in the smaller sizes, hence it is better to buy large sheets and cut them up. Bristol board is a very smooth paper, made in different thicknesses,

2-ply, 3-ply, 4-ply, etc.; 3-ply is generally used. For working drawings the cream or buff detail papers are much easier on the eyes than white papers. The cheap manilla papers should be avoided. A few cents more per yard is well spent in the increased comfort gained from working on good paper. In buying in quantity it is cheaper to buy roll paper by the pound. For maps

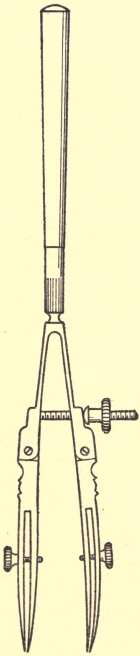


FIG. 24.—Railroad pen.

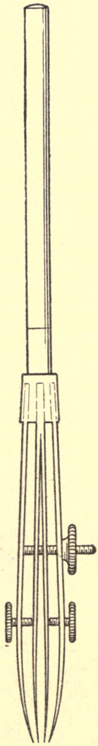


FIG. 25.—Double pen.

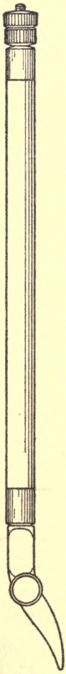


FIG. 26.—Curve pen.

or other drawings which are to withstand hard usage, mounted papers, with cloth backing are used. Drawings to be duplicated by blue printing are made on bond or ledger papers, or traced on tracing paper or tracing cloth. Tracing and the duplicating processes are described in Chapter XIII.

The foregoing instruments and materials are all that are needed in ordinary practice, and are as a rule, with the exception of paper, pencils, ink, erasers, etc., classed as supplies, what a draftsman is expected to take with him into a commercial drafting room.

There are many other special instruments and devices not necessary in ordinary work. With some of these the draftsman

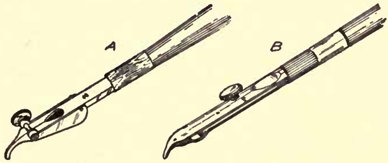


FIG. 27.—Lettering pens.

should be familiar, as they may be very convenient in some special cases, and are often found as part of a drafting room equipment.

The railroad pen is used for double lines. In selecting this

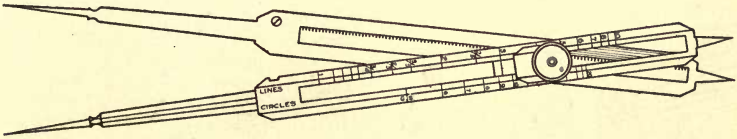


FIG. 28.—Proportional dividers.

pen notice that the pens are turned as illustrated in Fig. 24. Most forms have the pens in opposite directions. A much better pen for double lines up to 1/4″ apart is the border pen, Fig. 25, as it can be held down to the paper more satisfactorily. It may

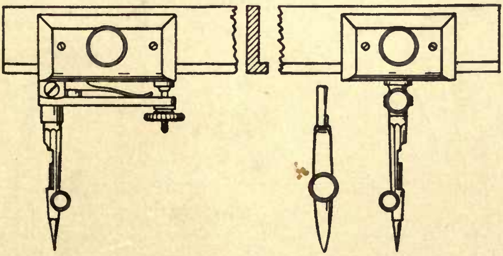


FIG. 29.—Beam compass.

be used for very wide solid lines by inking the middle space as well as the two pens.

The curve pen, Fig. 26, made with a swivel, for freehand curves, contours, etc., is of occasional value.

2

Payzant pens, Fig. 27A, for large single stroke lettering save a great deal of time. They are made in sizes from 1 to 6. Fig. 27B is the Shepard pen, made for the same purpose.

Proportional dividers, for enlarging or reducing in any propor-

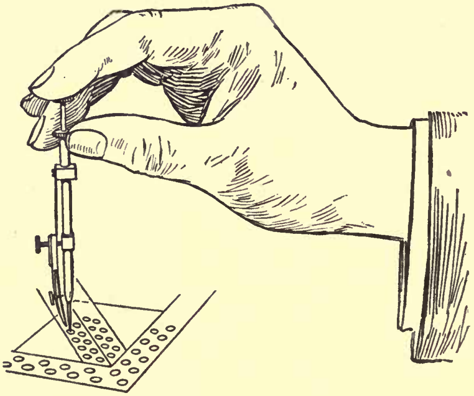


Fig. 30.—Drop pen.

tion, Fig. 28, are used in map work, patent office drawings, etc. The divisions marked "lines" are linear proportions, those marked "circles" give the setting for dividing a circle whose diameter is measured by the large end into the desired number of equal parts.

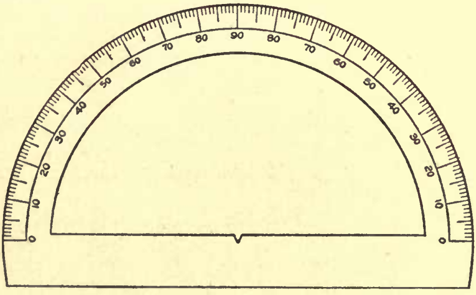


Fig. 31.—Protractor.

The beam compass is used for circles larger than the capacity of the compass and lengthening bar. A good form is illustrated in Fig. 29. The bar with shoulder prevents the parts from turning or falling off.

With the "drop pen" or rivet pen smaller circles can be made, and made much faster than with the bow pen. It is held as shown in Fig. 30, the needle point stationary and the pen revolving around it. It is of particular convenience in bridge and structural work, and in topographical drawing.

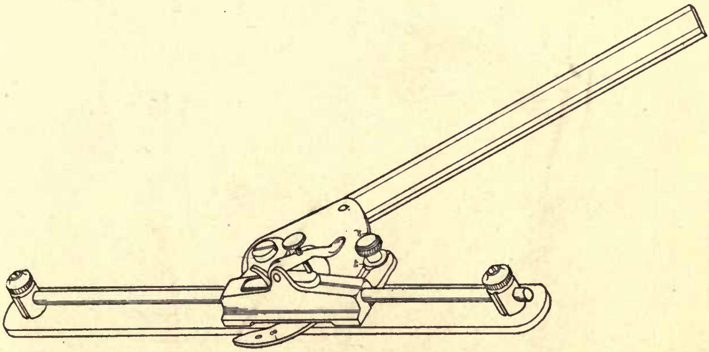


FIG. 32.—Section liner.

A protractor is a necessity in map and topographical work. A semicircular brass or German silver one, 6″ diameter, such as Fig. 31, will read to half degrees. They may be had with an arm and vernier reading to minutes.

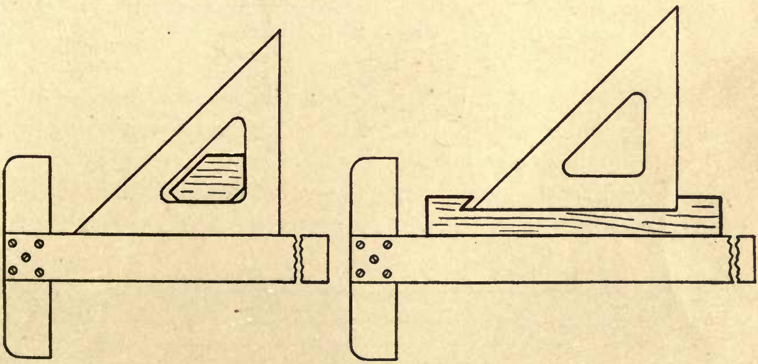


FIG. 33.—Section lining devices.

Section lining or "cross hatching" is a difficult operation for the beginner, but is done almost automatically by the experienced draftsman. Several instruments for mechanical spacing have been devised. For ordinary work they are not worth the trouble of setting up, and a draftsman should never become dependent upon them, but they are of limited value for careful drawing for reproduction. One form is shown in Fig. 32.

A home-made device may be made of a piece of thin wood or

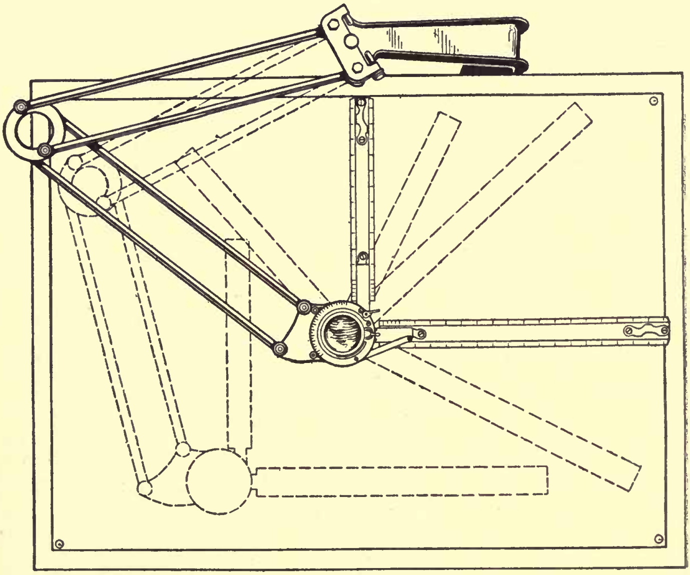


Fig. 34.—Universal drafting machine.

celluloid cut in one of the shapes shown in Fig. 33, and used by slipping the block and holding the triangle, then holding the block and moving the triangle.

There are several machines on the market designed to save time

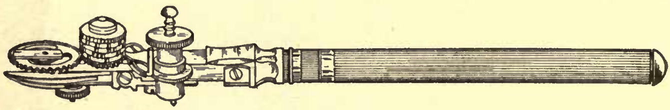


Fig. 35.—Dotting pen.

and trouble in drawing. The best known is the Universal Drafting Machine illustrated in Fig. 34. This machine, which combines the functions of T-square, triangle, scale and protractor, has had the test of ten years' use, and is used extensively in large drafting rooms, and by practising engineers and architects. It has been estimated that 25% of time in machine drawing and over 50 % in civil engineering work is saved by its use.

Vertical drawing boards with sliding parallel straight edges are preferred by some for large work.

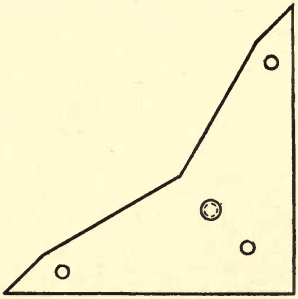


FIG. 36.

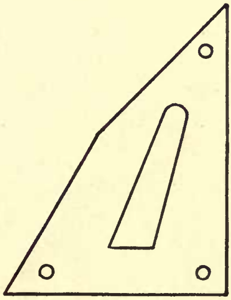


FIG. 37.

Several kinds of dotting pens have been introduced. The one illustrated in Fig. 35 is perhaps the best. When carefully handled it works successfully, and will make five different kinds of dotted and dashed lines. The length of the short dots may

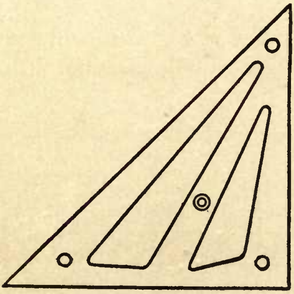


FIG. 38.

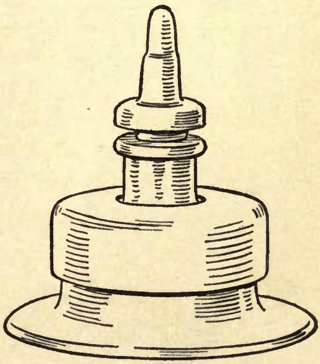


FIG. 39.

be varied by a slight inclination of the handle. For special work requiring a great many dotted lines it might prove to be a good investment.

A number of different forms of patented combination "triangles" have been devised. Of these the best known are the Kelsey, Fig. 36, the Rondinella, Fig. 37, and the Zange, Fig. 38.

Bottle holders prevent the possibility of ruining the drawing, table or floor by the upsetting of the ink bottle. Fig. 39 is a

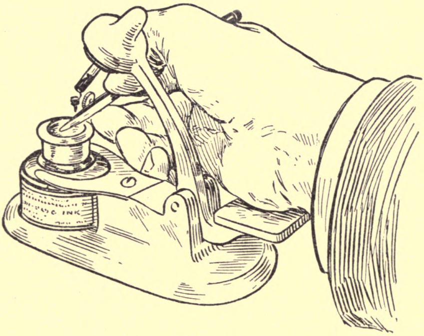


FIG. 40.

usual form, Fig. 40 a novelty by the Alteneder Co. by whose aid the pen may be filled with one hand and time saved thereby.

Erasing shields of metal or celluloid, meant to protect the drawing while an erasure is being made, are sold. Slots for the purpose may be cut as needed from sheet celluloid or tough paper.

CHAPTER III.

The Use of Instruments.

In beginning the use of drawing instruments particular attention should be paid to correct method in their handling. There are many instructions and cautions, whose reading may seem tiresome, and some of which may appear trivial, but the strict observance of all these details is really necessary, if one would become proficient in the art.

Facility will come with continued practice, but from the outset **good form** must be insisted upon. One might learn to write fairly, holding the pen between the fingers or gripped in the closed hand, but it would be poor form. It is just as bad to draw in poor form as to write in poor form. Bad form in drawing is distressingly common, and may be traced in every instance to lack of care or knowledge at the beginning, and the consequent formation of bad habits. These habits when once formed are most difficult to overcome.

All the mechanical drawing we do serves incidentally for practice in the use of instruments, but it is best for the beginner to learn the functions and become familiar with the handling and feel of each of his instruments by drawing two or three plates designed solely for that purpose, so that when real drawing problems are assigned the use of the instruments will be easy and natural, and there need be no distraction nor loss of time on account of correction for faulty manipulation.

Thus while the drawings are worth nothing when finished except to show the student's proficiency and skill, some such figures as those on pages 42 and 45 should be practised until he feels a degree of ability and assurance, and is not afraid of his instruments.

As these figures are for discipline and drill, the instructor should not accept a plate with the least inaccuracy, blot, blemish, or indication of ink erasure. It is a mistaken kindness to the beginner to accept faulty or careless work. The standard set at this time will be carried through his professional life, and he should learn that a good drawing can be made just as quickly as a poor one. Erasing is expensive and mostly preventable, and the student allowed to continue in a careless way will grow to regard his eraser and jack knife as the most important tools in his kit. The draftsman of course erases an occasional mistake, and instructions in making corrections may be given later in the course, but these first plates must not be erased.

Preparation for Drawing.

The drawing table should be set so that the light comes from the left, and adjusted to a convenient height for standing, that is, from 36 to 40 inches, with the board inclined at a slope of about 1 to 8. One may draw with more freedom standing than sitting.

The Pencil.

The pencil must be selected with reference to the kind of paper used. For line drawing on paper of such texture as "Normal" a pencil as hard as 6H may be used, while on Bristol, for example, a softer one would be preferred. Sharpen it to a long point as in Fig. 41 removing the wood with the penknife and sharpening the lead by rubbing it on the sand paper pad. A flat or wedge

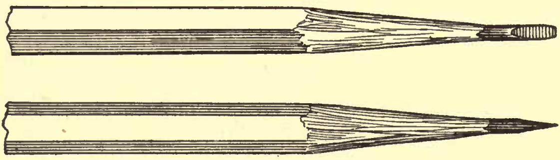


FIG. 41.—A wedge point.

point will not wear away in use as fast as a conical point, and on that account is preferred for straight line work by most draftsmen. By oscillating the pencil slightly while rubbing the lead on two opposite sides, an elliptical section is obtained. A softer pencil (2H) should be at hand, sharpened to a long conical point for sketching and lettering. Have the sand paper pad within reach and keep the pencils sharp. Pencil lines should be made lightly, but sufficiently firm and sharp to be seen distinctly without eye strain, for inking or tracing. The beginner's usual mistake in using a hard pencil is to cut tracks in the paper. Too much emphasis cannot be given to the importance of clean, careful, accurate penciling. Never permit the thought that poor penciling may be corrected in inking.

The T-Square.

The T-square is used only on the left edge of the drawing board (an exception to this is made in the case of a left-handed person, whose table should be arranged with the light coming from the right and the T-square used on the right edge).

Since the T-square blade is more rigid near the head than toward the outer end, the paper, if much smaller than the size of the board, should be placed close to the left edge of the board (within an inch or so) with its lower edge several inches from the bottom. With the T-square against the left edge of the board,

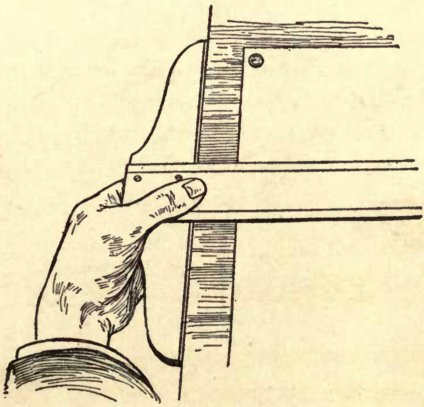


FIG. 42.

square the top of the paper approximately, hold in this position, slipping the T-square down from the edge, and put a thumb tack in each upper corner, pushing it in up to the head; move the T-square down over the paper to smooth out possible wrinkles and put thumb tacks in the other two corners.

The T-square is used manifestly for drawing parallel horizontal lines. These lines should always be drawn from left to right, consequently points for their location should be marked on the left side; vertical lines are drawn with the triangle set against the T-square, always with the perpendicular edge nearest the head of the square and toward the light. These lines are always drawn up from bottom to top, consequently their location points should be made at the bottom.

In drawing lines great care must be exercised in keeping them accurately parallel to the T-square or triangle, holding the pencil point lightly, but close against the edge, and not varying the angle during the progress of the line.

The T-square is adjusted by holding it in the position either of Fig. 42 the thumb up, and fingers touching the board under

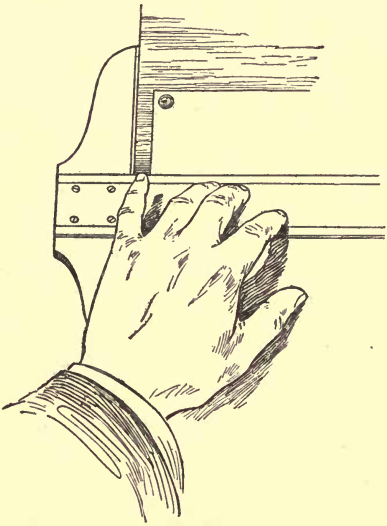


FIG. 43.

the head, or of Fig. 43, the fingers on the blade and the thumb on the board. In drawing vertical lines the T-square is held in position against the left edge of the board, the thumb on the blade, while the fingers of the left hand adjust the triangle, as illustrated in Fig. 44. One may be sure the T-square is in contact with the board by hearing the little double click as it comes against it.

Laying off the Drawing.

The paper is usually cut somewhat larger than the desired size of the drawing, and is trimmed to size after the work is finished. Suppose the plate is to be 9″ x 12″ with a half-inch border. Near the lower edge of the paper draw a horizontal line, and near the left edge a vertical line. If the lower left-hand corner of the board is known to be square these long vertical lines may be drawn with the T-square thrown around against the lower edge. With the scale flat on the paper mark off on these lines the length and width of the finished plate, and points

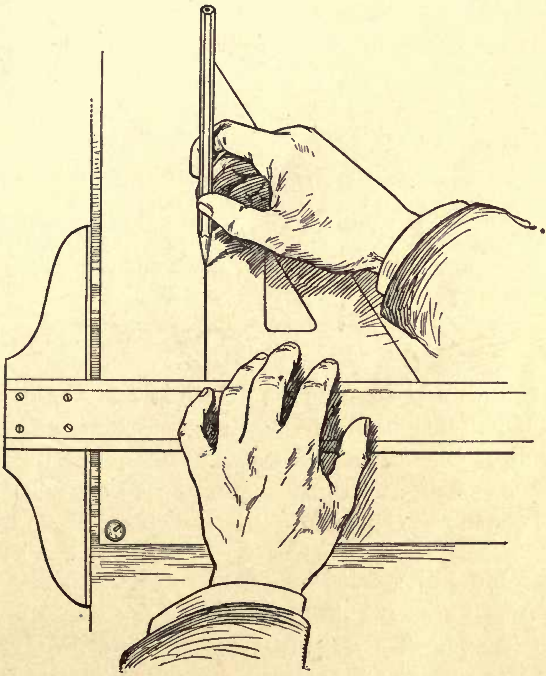


Fig. 44.

for the border 1/2″ inside these marks. Draw lines through these points giving the trimming line and the border line. These "points" should not be dots, or holes bored with the pencil, but short, light dashes.

Use of Dividers.

Suppose the space inside the border is to be divided into six equal parts by bisecting the left border line and dividing the lower border line into three parts. These divisions are made not with the scale but with the dividers. Facility in the use of this instrument is most essential, and quick and absolute control of its manipulation must be gained. It should be opened with one hand by pinching in the chamfer with the thumb and second finger. This will throw it into correct position with the thumb and forefinger on the outside of the legs and the second and third finger on the inside, with the head resting just above the second joint of the forefinger, Fig. 45. It is thus under perfect control,

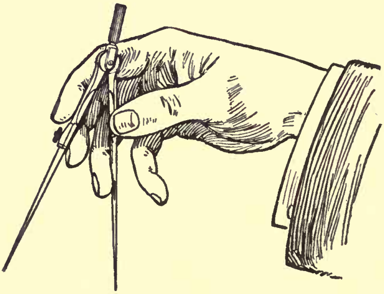


FIG. 45.

with the thumb and forefinger to close it and the other two to open it. This motion should be practised until an adjustment to the smallest fraction can be made. In coming down to small divisions the second and third fingers must be gradually slipped out from between the legs while they are closed down upon them.

To Divide a Line, by Trial.

In bisecting a line the dividers are opened roughly at a guess to one-half the length. This distance is stepped off on the line, holding the instrument by the handle with the thumb and forefinger. If the division be short the leg should be thrown out to one-half the remainder, estimated by the eye, without removing the other leg from its position on the paper, and the line spaced again with this setting, Fig. 46. If this should not come out exactly the operation may be repeated. With a little experience a line may be divided in this way very rapidly. Similarly a line may be divided into any number of equal parts, say five, by estimating the first division, stepping this lightly along the line, with the dividers held vertically by the handle, turning the instrument first in one direction and then in the other. If the last division fall short, one-fifth of the remainder should be added by opening the dividers, keeping the one point on the paper. If the last division be over, one fifth of the excess should be taken off and the line respaced. If it is found difficult to make this small adjustment accurately with the fingers, the hairspring may be used. It will be found more convenient to use the bow

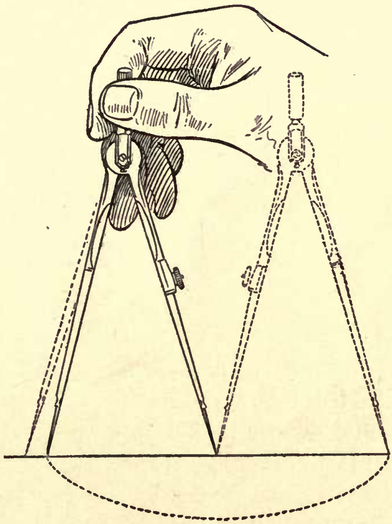


FIG. 46.—Bisecting a line.

spacers instead of the dividers for small or numerous divisions. Avoid pricking unsightly holes in the paper. The position of a small prick point may be preserved if necessary by drawing a little ring around it with the pencil.

Use of the Triangles.

We have seen that vertical lines are drawn with the triangle set against the T-square, Fig. 44. Usually the 60-degree triangle is used, as it has the longer perpendicular. In both penciling and inking, the triangles should always be used in contact with a guiding straight-edge.

With the T-square against the edge of the board, lines at 30 degrees, 45 degrees and 60 degrees may be drawn as shown in Fig. 47, the arrows showing the direction of motion. The two triangles may be used in combination for angles of 15, 75, 105 degrees, etc., Fig. 48. Thus any multiple of 15 degrees may be drawn directly, and a circle may be divided with the 45-degree

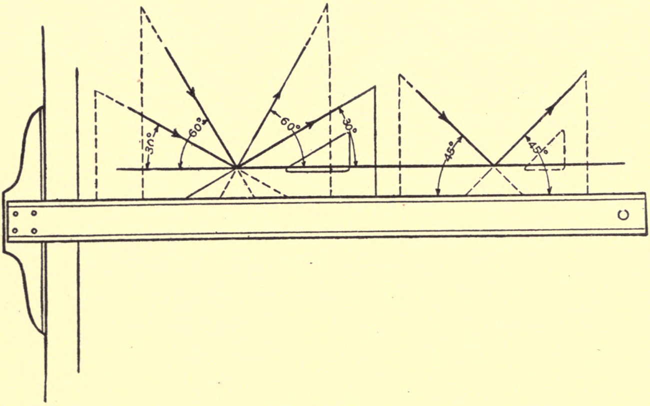


Fig. 47.

triangle into 4 or 8 parts, with the 60-degree triangle into 6 or 12 parts, and with both into 24 parts.

To draw a parallel to any line, Fig. 49, adjust to it a triangle

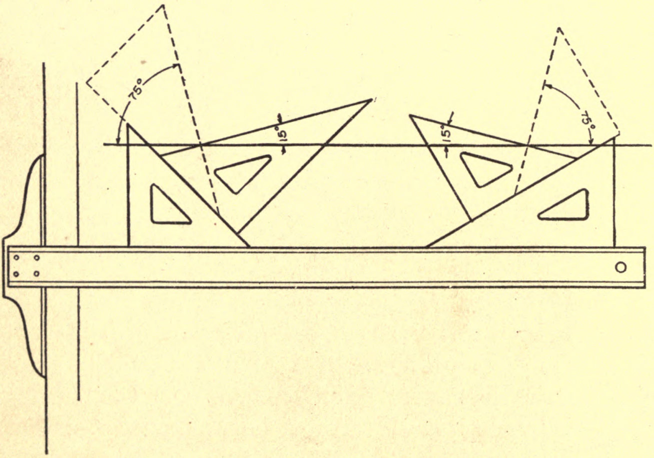


Fig. 48.

held against the T-square or other triangle, hold the guiding edge in position and slip the first triangle on it to the required position.

To draw a perpendicular to any line, Fig. 50, fit the hypothenuse of a triangle to it, with one edge against the T-square or other triangle, hold the T-square in position and turn the triangle until its other side is against the edge, the hypothenuse will then be perpendicular to the line. Move it to the required position.

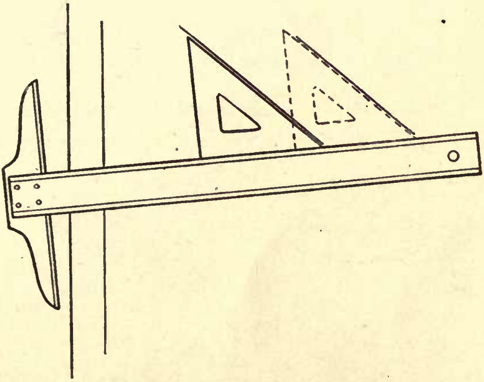


FIG. 49.—To draw parallel lines.

Never attempt to draw a perpendicular to a line by merely placing one leg of the triangle against it. Never work to the extreme corner of a triangle, but keep the T-square away from the line.

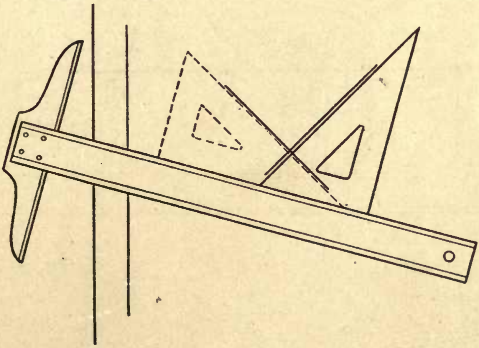


FIG. 50.—To draw perpendicular lines.

Use of the Compasses.

The compass has the same general shape as the dividers and is manipulated in a similar way. Its needle point should first of all be adjusted by turning it with the shoulder point out, inserting the pen in the place of the pencil leg and setting the needle a trifle longer than the pen. The needle point should be kept in this position so as to be always ready for the pen, and the lead adjusted to it. The lead should be sharpened on the sand

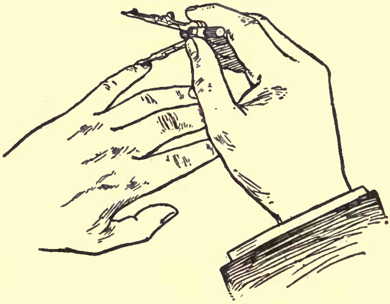


FIG. 51.

paper to a fine wedge or long bevel point. Radii should be pricked off or marked on the paper and the pencil leg adjusted to the points. The needle point may be guided to the center with the little finger of the left hand, Fig. 51. When the lead is

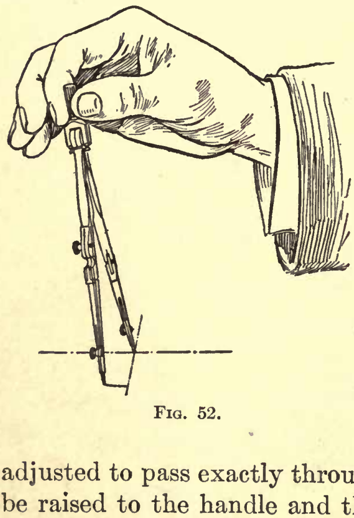


FIG. 52.

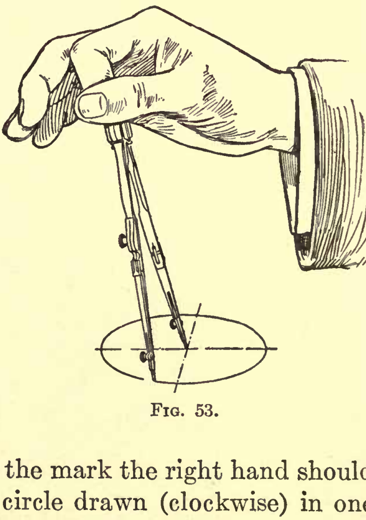


FIG. 53.

adjusted to pass exactly through the mark the right hand should be raised to the handle and the circle drawn (clockwise) in one sweep by turning the compass, rolling the handle with the thumb and forefinger, inclining it slightly in the direction of the line,

Fig. 52. The position of the fingers after the revolution is illustrated in Fig. 53. Circles up to perhaps three inches in diameter may be drawn with the legs straight but for larger sizes both the needle-point leg and the pencil leg should be turned

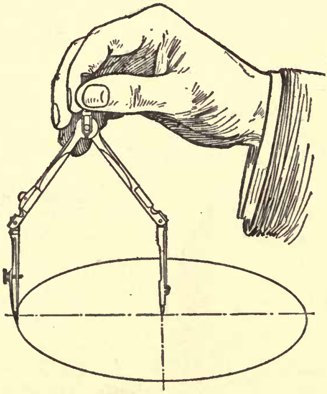


Fig. 54.

at the knuckle joints so as to be perpendicular to the paper, Fig. 54. The 5 1/2-inch compass may be used in this way for circles up to perhaps ten inches in diameter; larger circles are made by using the lengthening bar, as illustrated in Fig. 55. In

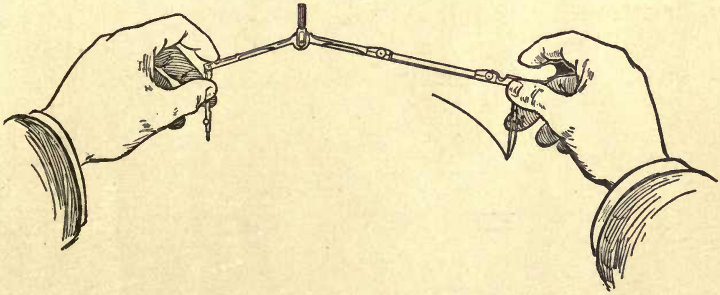


Fig. 55.—Use of lengthening bar.

drawing concentric circles the smallest should always be drawn first.

The bow instruments are used for small circles, particularly when a number are to be made of the same diameter. In changing the setting, to avoid wear and final stripping of the thread, the pressure of the spring against the nut should be relieved by holding the points in the left hand and spinning the nut in or out with the finger. Small adjustments should be made with one hand, with the needle point in position on the paper, Fig. 56.

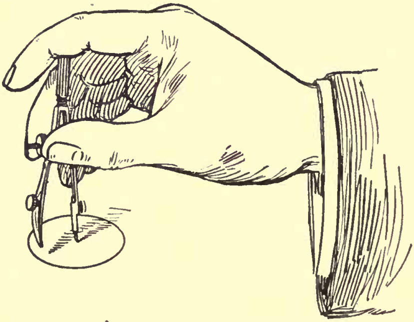


FIG. 56.

Use of the Scale.

In representing objects which are larger than can be drawn to their natural or full size it is necessary to reduce the dimensions on the drawing proportionately, and for this purpose the architects' scale is used. The first reduction is to what is commonly called half size or correctly speaking, to the scale of 6″ = 1′; that is, each dimension is reduced one-half. This scale is used in working drawings even if the object be only slightly larger than could be drawn full size, and is generally worked with the full-size scale, halving the dimensions mentally. If this scale is too

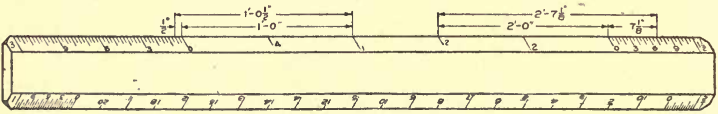


FIG. 57.

large for the paper the drawing is made to the scale of three inches to the foot, often called "quarter size," that is, three inches measured on the drawing is equal to one foot on the object. This is the first scale of the usual commercial set, on it the distance of three inches is divided into twelve equal parts and each of these subdivided into eighths. This distance should be thought of not as three inches but as a foot divided into inches and eighths of inches. It is noticed that this foot is divided with the zero on the inside, the inches running to the left and the feet to the right, so that dimensions given in feet and inches may be read directly, as 2 ft. 7 1/8″, Fig. 57. On the other end will be found the scale of 1 1/2 inches equals one foot, or eighth size, with the distance of one and one-half inches divided on the right of the zero into twelve parts and subdivided into quarter inches, and the foot divisions to the left of the zero, coinciding with the marks of the 3″ scale.

If the 1 1/2″ scale is too large for the object, the next commercial size is to the scale of one inch equals one foot, and so on down as shown in the following table.

Full size		3/4″ = 1′
Scale 6″	= 1′	1/2″ = 1′
4″	= 1′ (rarely used)	3/8″ = 1′
3″	= 1′	1/4″ = 1′
2″	= 1′ (rarely used)	3/16″ = 1′
1 1/2″	= 1′	1/8″ = 1′
1″	= 1′	3/32″ = 1′

The scale 1/4″ equals 1 ft. is the usual one for ordinary house plans and is often called by architects the "quarter scale." This term should not be confused with the term "quarter size," as the former means 1/4″ to 1 ft. and the latter 1/4″ to 1 inch.

A circle is generally given in terms of its diameter. To draw it the radius is necessary. In drawing to half size it is thus often convenient to lay off the amount of the diameter with a 3-in. scale and to use this distance as the radius.

As far as possible successive measurements on the same line should be made without shifting the scale.

For plotting and map drawing the "engineers' scale" of decimal parts 10, 20, 30, 40, 50, 60, 80, 100 to the inch, is used. This scale should never be used for machine or structural work.

Inking.

After being penciled, drawings are finished either by inking on the paper, or in the great majority of work, by tracing in ink on tracing cloth. The beginner should become proficient in inking both on paper and cloth.

The ruling pen is never used freehand, but always in connection with a guiding edge, either T-square, triangle, straight-edge or curve. The T-square and triangle should be held in the same positions as for penciling. It is bad practice to ink with the triangle alone.

To fill the pen take it to the bottle and touch the quill filler between the nibs, being careful not to get any ink on the outside of the blades. Not more than three-sixteenths of an inch should be put in or the weight of the ink will cause it to drop out in a blot. The pen should be held as illustrated in Fig. 58, with the thumb and second finger in such position that they may be used in turning the adjusting screw, and the handle resting on the

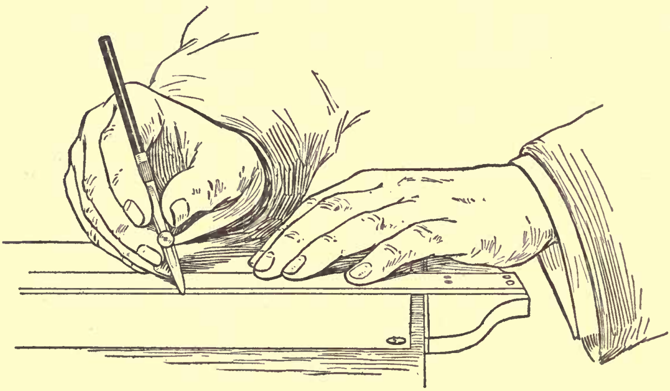


Fig. 58.—Holding the pen.

forefinger. This position should be observed carefully, as the tendency will be to bend the second finger to the position in which a pencil or writing pen is held, which is obviously convenient in writing to give the up stroke, but as this motion is not required with the ruling pen the position illustrated is preferable.

For full lines the screw should be adjusted to give a strong line, of the size of the first line of Fig. 62. A fine drawing does not mean a drawing made with fine lines, but with uniform lines, and accurate joints and tangents.

The pen should be held against the straight edge with the blades parallel to it, the handle inclined slightly to the right and always kept in a plane through the line perpendicular to the paper. The pen is thus guided by the upper edge of the ruler, whose distance from the pencil line will therefore vary with its thickness, and with the shape of the under blade of the pen, as illustrated in enlarged scale in Fig. 59. If the pen is thrown out from the perpendicular as at *B* it will run on one blade and a line ragged on one side will result. If turned in from the perpendicular as at *C* the ink is very apt to run under the edge and cause a blot.

A line is drawn with a whole arm movement, the hand resting on the tips of the third and fourth fingers, keeping the angle of inclination constant. Just before reaching the end of the line the two guiding fingers on the straight edge should be stopped,

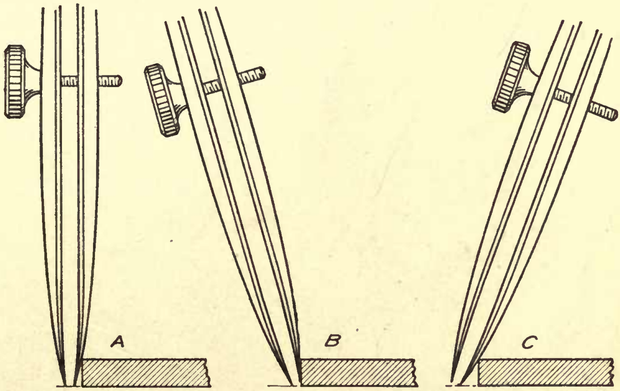


Fig. 59.—Correct position at *A*.

and, without stopping the motion of the pen, the line finished with a finger movement. Short lines are drawn with this finger movement alone. When the end of the line is reached lift the pen quickly and move the straight edge away from the line. The pressure on the paper should be light, but sufficient to give a clean cut line, and will vary with the kind of paper and the sharpness of the pen, but the pressure against the T-square should be only enough to guide the direction.

If the ink refuses to flow it is because it has dried and clogged in the extreme point of the pen. This clot or obstruction may be removed by touching the pen on the finger, or by pinching the blade slightly, breaking it up. If it still refuses to start it should be wiped out and fresh ink added. The pens must be wiped clean after using or the ink will corrode the steel and finally destroy them.

Instructions in regard to the ruling pen apply also to the compass pen. It should be kept perpendicular by using the knuckle joint, and the compass inclined slightly in the direction of the line. In adjusting the compass for an arc which is to connect other lines the pen point should be brought down very close to the paper without touching it to be sure that the setting is exactly right.

It is a universal rule in inking that circles and circle arcs must be drawn first. It is much easier to connect a straight line to a curve than a curve to a straight line.

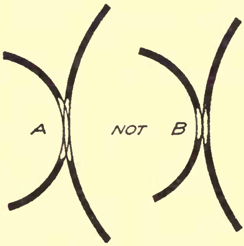


FIG. 60.

It should be noted particularly that two lines are tangent to each other when their centers are tangent, and not when the lines simply touch each other, thus at the point of tangency the width will be equal to the width of a single line, Fig. 60 *A*.

After reading these paragraphs the beginner had best take a blank sheet of paper and cover it with ink lines of varying lengths and weights, practising starting and stopping on penciled limits, until he feels acquainted with the pens. If in his set there are two pens of different sizes the larger one should be used, as it fits the hand of the average man better than the smaller one, holds more ink, and will do just as fine work.

Faulty Lines.

If inked lines appear imperfect in any way the reason should be ascertained immediately. It may be the fault of the pen, the ink, the paper, or the draftsman, but with the probabilities greatly in favor of the last. Fig. 61 illustrates the characteristic appearance of several kinds of faulty lines. The correction in each case will suggest itself.

High-grade pens usually come from the makers well sharpened. Cheaper ones often need dressing before they can be used satisfactorily. If the pen is not working properly it must be sharpened as described in Chapter XIV, page 257.

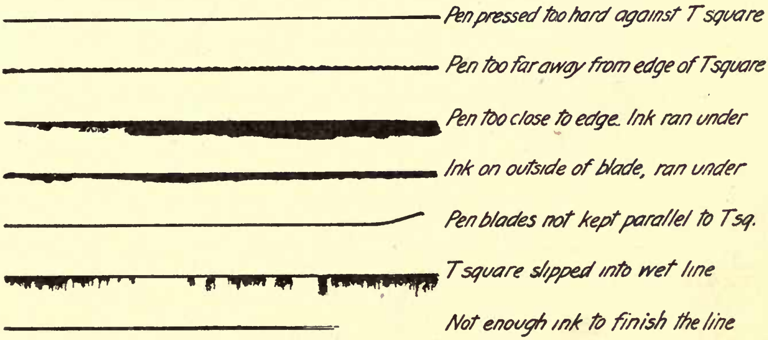


FIG. 61.—Faulty lines.

The Alphabet of Lines.

As the basis of the drawing is the line, a set of conventional symbols covering all the lines needed for different purposes may properly be called an alphabet of lines. There is as yet no universally adopted standard, but the following set is adequate, and represents the practice of a majority of the larger concerns of this country.

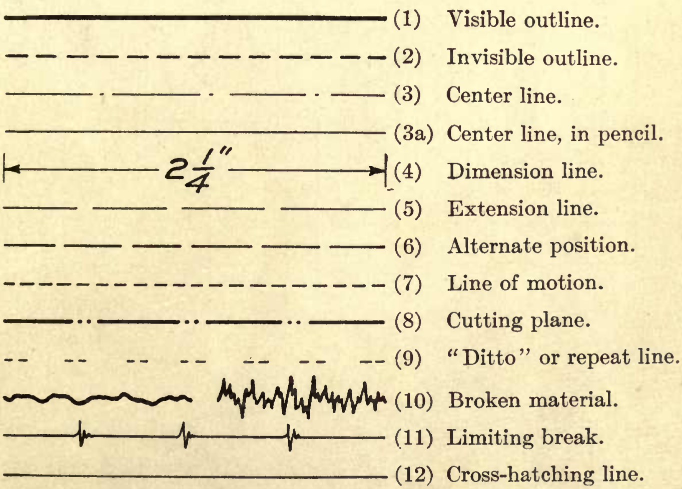


FIG. 62.—The alphabet of lines.

It is of course not possible to set an absolute standard of weight for lines, as the proper size to use will vary with different kinds

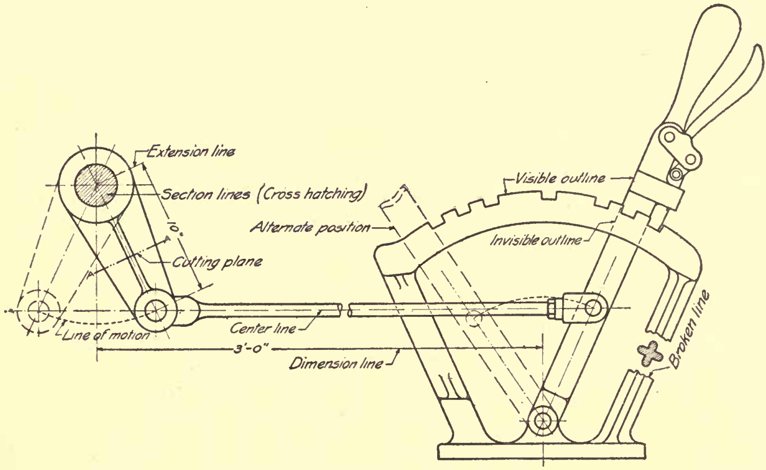


Fig. 63.—The alphabet illustrated.

and sizes of drawings, but it is possible to maintain a given proportion.

Visible outlines should be strong full lines, at least one-sixty-fourth of an inch on paper drawings, and even as wide as one-

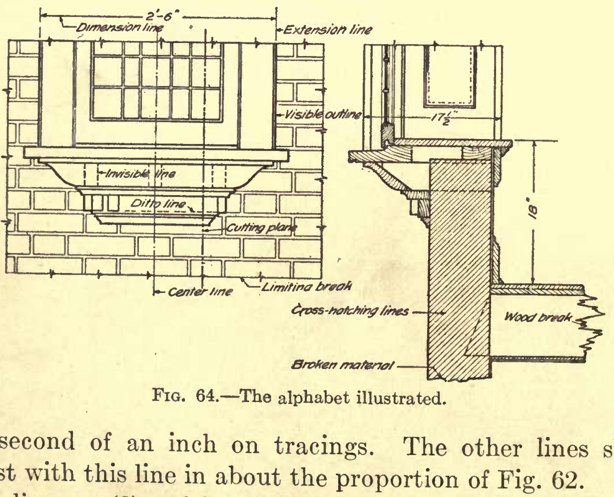


Fig. 64.—The alphabet illustrated.

thirty-second of an inch on tracings. The other lines should contrast with this line in about the proportion of Fig. 62.

Dash lines, as (2) and (7), should always have the space between dashes much shorter than the length of the dash. Figs. 63 and 64 illustrate the use of the alphabet of lines.

The Use of the French Curve.

The French curve, as has been stated on page 14, is a ruler for non-circular curves. When sufficient points have been determined it is best to sketch in the line lightly in pencil freehand, without losing the points, until it is clean, smooth, continuous, and satisfactory to the eye. The curve should then be applied to it, selecting a part that will fit a portion of the line most nearly, and noting particularly that the curve is so laid that the direction of its increase in curvature is in the direction of increasing curvature of the line, Fig. 65. In drawing the part of the line matched

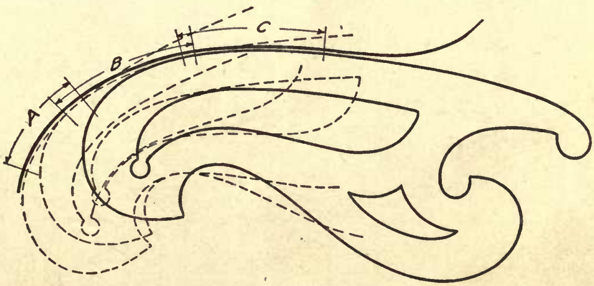


FIG. 65.—Use of the curve.

by the curve, always stop a little short of the distance that seems to coincide. After drawing this portion the curve is shifted to find another part that will coincide with the continuation of the line. In shifting the curve care should be taken to preserve the smoothness and continuity and to avoid breaks or cusps. This may be done if in its successive positions the curve is always adjusted so that it conincides for a little distance with the part already drawn. Thus at each joint the tangents must coincide.

If the curved line is symmetrical about an axis, after it has been matched accurately on one side, marks locating the axes may be made in pencil on the curve and the curve reversed. In such a case exceptional care must be taken to avoid a "hump" at the joint. It is often better to stop a line short of the axis on each side and to close the gap afterwards with another setting of the curve.

When inking with the curve the pen should be held perpendicularly and the blades kept parallel to the edge. Inking curves will be found to be excellent practice.

Sometimes, particularly at sharp turns, a combination of circle arcs and curve may be used, as for example in inking an eccentric ellipse, the sharp curves may be inked by selecting a center on the major axis by trial, and drawing as much of an arc as will practically coincide with the ends of the ellipse, then finishing the ellipse with the curve.

The experienced draftsman will sometimes ink a curve that cannot be matched accurately, by varying the distance of the pen point from the ruling edge as the line progresses, but the beginner should not attempt it.

Exercises in the Use of Instruments.

The twelve following figures are given simply as a typical set of progressive exercises for practice in the use of the instruments. More or fewer may be used according to the student's evidence of ability. The geometrical figures of Chapter IV may be used for the same purpose.

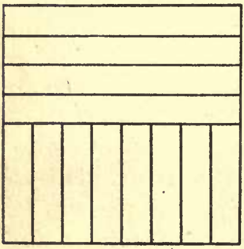


Fig. 66.

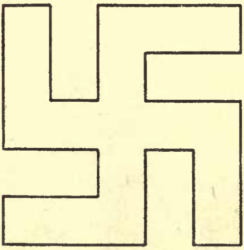


Fig. 67.

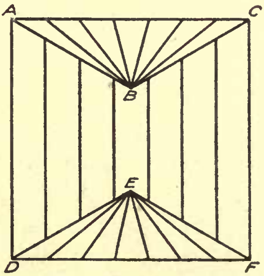


Fig. 68.

Lay off a 9″ x 12″ plate, with 1/2″ border. Divide the space inside the border into six equal parts, with the dividers. Locate the center of each space by drawing short intersecting portions of its diagonals.

Fig. 66. **An Exercise for the T-square, Triangle and Scale.** Through the center of the space draw a horizontal and a vertical line, measuring on these lines as diameters lay off a three-inch square. Along the lower side and the upper half of the left side measure 3/8″ spaces with the scale. Draw

all horizontal lines with the T-square and all vertical lines with the T-square and triangle.

Fig. 67. **A "Swastika."** For T-square, triangle and dividers. Draw three-inch square. Divide left side and lower side into five equal parts with the dividers. Draw horizontal and vertical lines across the square through these points. Erase the parts not needed.

Fig. 68. **Converging Lines.** Draw three-inch square. Draw lines *AB*, *BC*, *DE* and *EF* at 30 degrees. Divide lower side into seven equal parts, with the dividers. Draw the vertical lines, and mark divisions on *AC* with the pencil as each line

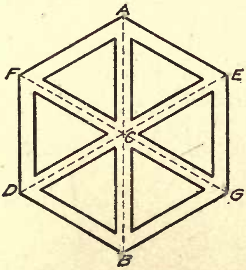


FIG. 69.

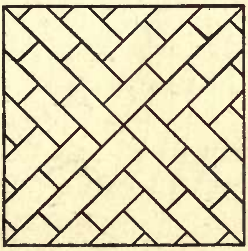


FIG. 70.

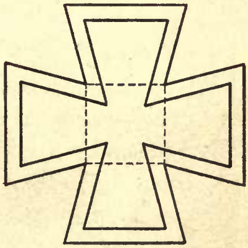


FIG. 71.

is drawn. Through the division points on top and bottom draw the converging lines using the triangle alone as a straight-edge.

Fig. 69. **A Hexagonal Figure.** For 30°–60° triangle and bow points (spacers).

Through the center of the space draw the three construction lines, *AB* vertical, *DE* and *FG* at 30 degrees. Measure *CA* and *CB* 1 1/2″ long. Draw *AE*, *AF*, *DB*, and *BG* at 30 degrees. Complete hexagon by drawing *DF* and *GE* vertical. Set spacers to 3/32″. Step off 3/32″ on each side of the center lines, and 3/16″ from each side of hexagon. Complete figure as shown, with triangle against T-square.

Fig. 70. **A Street Paving Intersection.** For 45-degree triangle and scale.

An exercise in starting and stopping short lines. Draw three-inch square. Draw diagonals with 45-degree triangle. With scale lay off 3/8″ spaces along the diagonals, from their intersection. With 45-degree triangle complete figure, finishing one-quarter at a time.

Fig. 71. **A Maltese Cross.** For T-square, spacers, and both triangles.
Draw three-inch square and one-inch square. From the corners of inner square draw lines to outer square at 15 degrees and 75 degrees, with the two triangles in combination. Mark points with spacers 3/16″ inside of each line of this outside cross, and complete figure with triangles in combination.

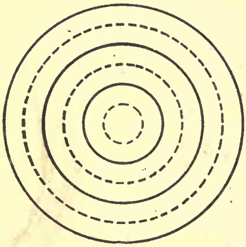


Fig. 72.

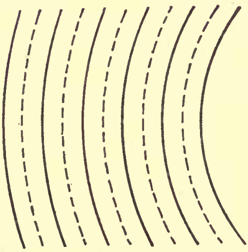


Fig. 73.

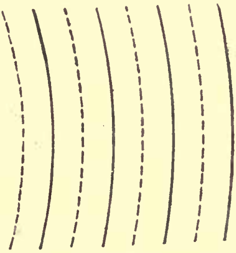


Fig. 74.

Fig. 72. **Concentric Circles.** For compass (legs straight) and scale.
Draw horizontal line through center of space. On it mark off radii for six concentric circles 1/4″ apart. In drawing concentric circles always draw the smallest first. The dotted circles are drawn in pencil with long dashes, and inked as shown.

Fig. 73. **Concentric Arcs.** For compass (knuckle joints bent).
On horizontal center line mark off eleven points 1/4″ apart, beginning at left side of space. Draw horizontal limiting lines (in pencil only) 1 1/2″ above and below center line.

Fig. 74. **Concentric Arcs.** For compass and lengthening bar.
On horizontal center line mark off eight points 3/8″ apart, beginning at right side of space Center of arcs is center of Fig. 72.

Fig. 75. **Tangent Arcs.** For accuracy with compass and dividers.
Draw a circle three inches in diameter. Divide the circumference into five equal parts by trial with dividers. From these points draw radial lines and divide each into four

equal parts with spacers. With these points as centers draw the semicircles as shown. The radial lines are not to be inked.

Fig. 76. **Tangent Circles and Lines.** For accuracy with compass and triangles.

On base *AB*, 3 1/2″ long construct an equilateral triangle, using the 60-degree triangle. Bisect the angles with the 30-degree angle, extending the bisectors to the opposite sides. With these middle points of the sides as centers and radius equal to 1/2 the side, draw arcs cutting the bisectors. These intersections will be centers for the

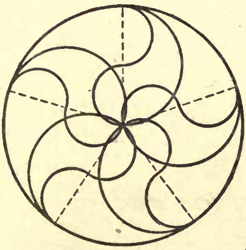


FIG. 75.

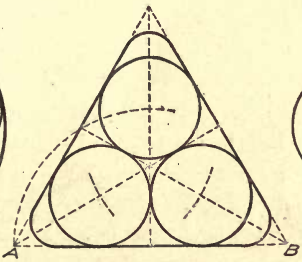


FIG. 76.

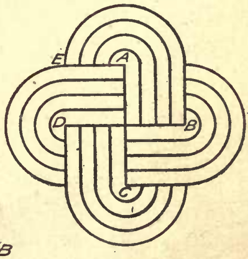


FIG. 77.

inscribed circles. With centers on the intersection of these circles and the bisectors, round off the points of the triangle as shown.

Remember the rule that circles are inked before straight lines. Construction lines are not to be inked.

Fig. 77. **Tangents to Circle Arcs.** For bow compasses.

Draw one and one-half inch square about center of space. Divide *AE* into four 3/16″ spaces, with scale. With bow pencil and centers *A*, *B*, *C*, *D* draw four semicircles with 3/8″ radius and so on. Complete figure by drawing the horizontal and vertical tangents as shown.

A PAGE OF CAUTIONS.

Never use the scale as a ruler.
Never draw with the lower edge of the T-square.
Never cut paper with a knife and the edge of the T-square as a guide.
Never use the T-square as a hammer.
Never put either end of a pencil in the mouth.
Never jab the dividers into the drawing board.
Never oil the joints of compasses.
Never use the dividers as reamers or pincers or picks.
Never take dimensions by setting the dividers on the scale.
Never lay a weight on the T-square to hold it in position.
Never use a blotter on inked lines.
Never screw the nibs of the pen too tight.
Never run backward over a line either with pencil or pen.
Never leave the ink bottle uncorked.
Never hold the pen over the drawing while filling.
Never dilute ink with water. If too thick throw it away. (Ink once frozen is worthless afterward.)
Never try to use the same thumb tack holes when putting paper down a second time.
Never scrub a drawing all over with the eraser after finishing. It takes the life out of the inked lines.
Never begin work without wiping off table and instruments.
Never put instruments away without cleaning. This applies with particular force to pens.
Never put bow instruments away without opening to relieve the spring.
Never fold a drawing or tracing.
Never use cheap materials of any kind.

CHAPTER IV.

APPLIED GEOMETRY.

With the aid of a straight-edge and compass all pure geometrical problems may be solved. The principles of geometry are constantly used in mechanical drawing, but as the geometrical solution of problems and construction of figures differs in many cases from the draftsman's method, equipped as he is with instruments for gaining time and accuracy, such problems are not included here. For example, there are several geometrical methods of erecting a perpendicular to a given line, in his ordinary practice the draftsman equipped with T-square and triangles uses none of them. The application of these geometrical methods might be necessary occasionally in work where the usual drafting instruments could not be used, as for example in laying out full size sheet metal patterns on the floor. It is assumed that students using this book are familiar with the elements of plane geometry and will be able to apply their knowledge. If a particular problem is not remembered, it may readily be referred to

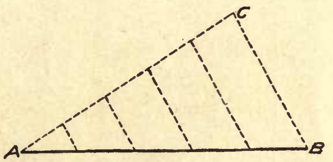


FIG. 78.

in any of the standard hand-books. There are some constructions however with which the draftsman should be familiar as they will occur more or less frequently in his work. The few problems in this chapter are given on this account, and for the excellent practice they afford in the accurate use of instruments as well.

The "trial method" of dividing a line was explained in the previous chapter. A convenient geometrical method is illustrated in Fig. 78. To divide the line *AB* into (say) five equal parts, draw any line *AC* indefinitely, on it step off five divisions of convenient length, connect the last point with *B*, draw lines through the points parallel to *CB* intersecting *AB*, using triangle and straight-edge.

To transfer a given polygon *ABCD* **to a new base** *A′B′*, Fig. 79. With radii *AC* and *BC* describe intersecting arcs from centers *A′B′*, locating the point *C′*. Similarly with radii *AD* and *BD*

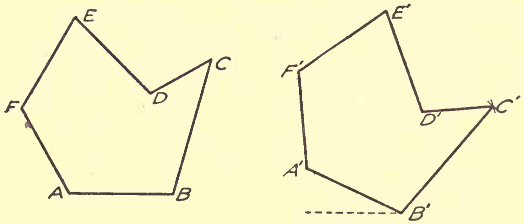


Fig. 79.

locate the point *D′*. Connect *BC* and *CD*, and continue the operation.

To inscribe a regular octagon in a given square, Fig. 80. Draw the diagonals of the square. With the corners of the square as centers and radius of half the diagonal draw arcs intersecting the sides of the square and connect these points.

To draw a circular arc through three given points *A*, *B*, and *C*,

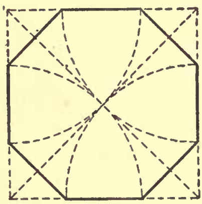


Fig. 80.

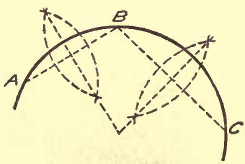


Fig. 81.

Fig 81. Join *AB* and *BC*, bisect *AB* and *BC* by perpendiculars. Their intersection will be the center of the required circle.

To draw an arc of a given radius *R* **tangent to two given lines** *AB* **and** *CD*, Fig. 82. Draw lines parallel to *AB* and *CD* at distance *R* from them. The intersection of these lines will be the center of the required arc.

To draw a reverse or "ogee" curve connecting two parallel lines *AB* and *CD*, Fig. 83. Erect perpendiculars at *B* and *C*.

Any arcs tangent to the lines must have their centers on these perpendiculars. Join *B* and *C* by a straight line. Assume point *E* on this line through which the curve is desired to pass, and bisect *BE* and *EC* by perpendiculars. Any arc to pass through *B* and *E* must have its center on a perpendicular at the middle point. The intersection therefore of these perpendiculars with the two first perpendiculars will be the centers for arcs *BE* and

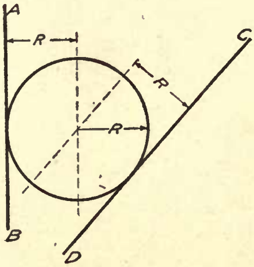


FIG. 82.

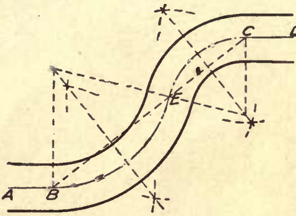


FIG. 83.

EC. This line might be the center line for a curved road or pipe.

To lay off on a straight line the approximate length of a circle-arc, Fig. 84. Let *AB* be the given arc. At *A* draw the tangent *AD* and chord *AB* produced. Lay off *AC* equal to half the chord *AB*. With center *C* and radius *CB* draw an arc intersecting *AB* at *E*, then *AE* will be equal in length be to the arc *AB* (very

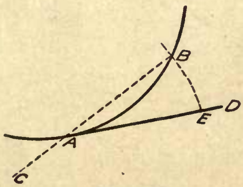


FIG. 84.

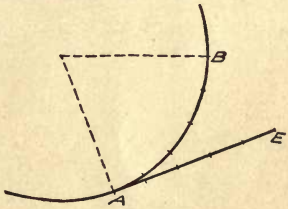


FIG. 85.

nearly). If the given arc is greater than 60 degrees it should be subdivided.*

In ordinary work the usual way of **rectifying an arc** is to step around it with the dividers, in spaces small enough as practically to coincide with the arc, and to step off the same number on the right line, as in Fig. 85.

* In this (Professor Rankine's) solution, the error varies as the fourth power of the subtended angle. At 60 degrees the line will be 1/900 part short.

In cutting a right circular cone by planes at different angles four curves called the **conic sections** are obtained, Fig. 86. These are the circle, cut by a plane perpendicular to the axis; the ellipse, cut by a plane making a greater angle with the axis than the elements do; the parabola, cut by a plane making the same angle with the axis as the elements do; the hyperbola, cut by a plane

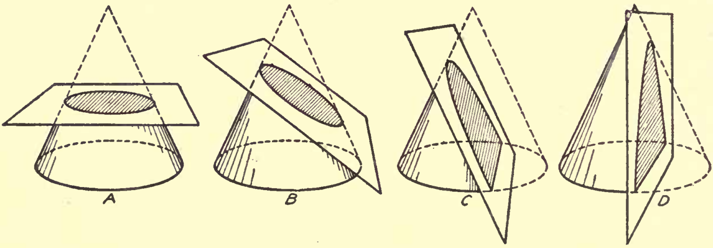


FIG. 86.—The conic sections.

making a smaller angle than the elements do. These curves are studied mathematically in analytic geometry but may be drawn without a knowledge of their equations by knowing something of their characteristics.

As an ellipse is the projection of a circle viewed obliquely it is met with in practice oftener than the other conics, aside from the circle, and draftsmen should be able to construct it readily, hence several methods are given for its construction, both as a true ellipse and as an approximate curve made by circle-arcs. In the great majority of cases when this curve is required its long and short diameters, *i.e.*, its major and minor axes are known.

Ellipse—First Method.

The most accurate method for determining points on the curve is shown in Fig. 87. With C as center describe circles on the two diameters. From a number of points on the outer circle as P and Q draw radii CP, CQ, etc., intersecting the inner circle at P', Q', etc. From P and Q draw lines parallel to CD, and from P' and Q' lines parallel to CB. The intersection of the lines through P and P' gives one point on the ellipse. The intersection of the lines through Q and Q' another point, and so on. For accuracy the points should be taken closer together toward the major axis. The process may be repeated in the four quadrants and the curve sketched in lightly freehand, or one quadrant only may be constructed and the remaining three repeated by marking the French curve. A tangent at any point *H* may be drawn by projecting the point to the outer circle at *K* and drawing the auxiliary tangent *KL* cutting the major axis at *L*. From *L* draw the required tangent *LH*.

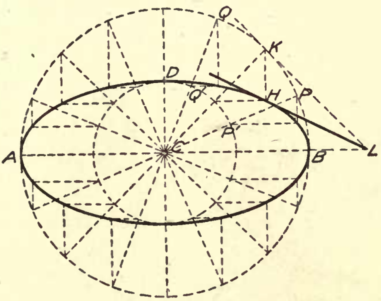


FIG. 87.

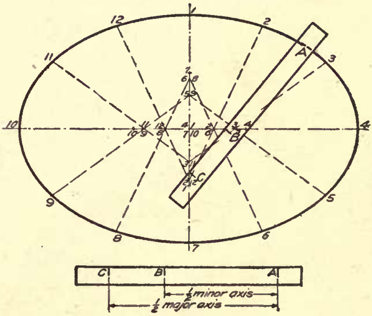


FIG. 88.

Ellipse—Trammel Method. Fig. 88.

On the straight edge of a strip of paper, thin cardboard or sheet celluloid mark the distance *PQ* equal to one-half the major axis and *PR* equal to one-half the minor axis. If the strip be moved keeping *Q* on the minor axis and *R* on the major axis, *P*

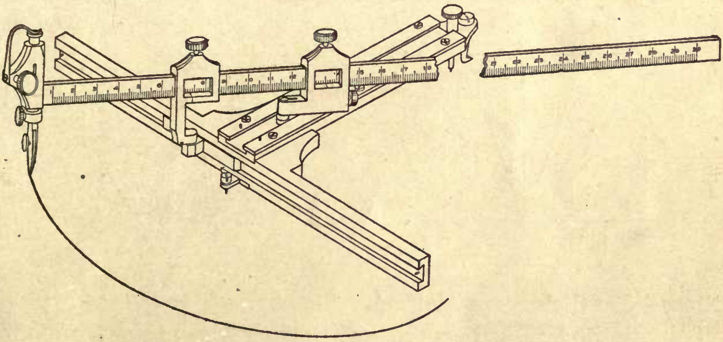


FIG. 89.—An Ellipsograph.

will give points on the ellipse. This method will be found very convenient, as no construction is required, but for accurate results great care should be taken to keep the points *P* and *Q* exactly on the axes. The ellipsograph, Fig. 89, is constructed on the principle of this method.

Ellipse—Pin and String Method. Fig. 90.

This well-known method sometimes called the "gardener's ellipse" is often used for large work, and is based on the mathematical principle of the ellipse that the sum of the distances from any point on the curve to two fixed points called the foci is a constant, and is equal to the major axis. The foci may thus be determined by making *DF* and *DF′* equal to *AC*. Drive pins at the points *D*, *F*, and *F′* and tie an inelastic thread or cord tightly around the three pins. If the pin *D* be removed and a marking point moved in the loop, keeping the cord taut, it will describe a true ellipse. The bisector of the angle between the focal lines will be normal to the curve, hence a tangent at any point *L* may be drawn by bisecting the exterior angle *MLF*.

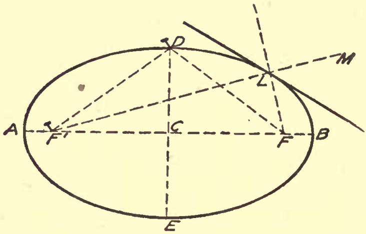


Fig. 90.

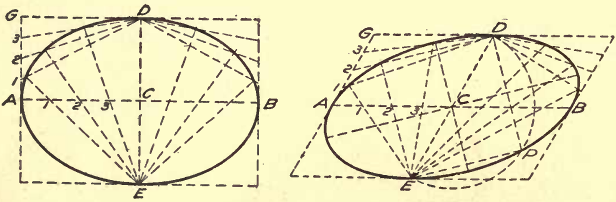


Fig. 91.

Ellipse—Parallelogram Method. Fig. 91.

This method may be used with either the major and minor axes or with any pair of conjugate diameters. On the diameters construct the parallelogram *ABDE*. Divide *AC* into any number of equal parts and *AG* into the same number of equal parts, numbering the points from *A*. Through these points draw lines from *D* and *E* as shown. Their intersections will be points on the curve.

To determine the major and minor axes of an ellipse, the conjugate axes being given. The property of conjugate diameters is that each is parallel to the tangent to the curve at the extremities of the other. At *C* draw a semicircle with radius *CE*. Connect the point of intersection *P* of this circle and the ellipse with *D* and *E*. The major and minor axes will be parallel to the chords *DP* and *EP*.

Approximate Ellipse with Four Centers. Fig. 92.

Join *A* and *D*. Lay off *DF* equal to *AC*−*DC*. Bisect *AF* by a perpendicular crossing *AC* at *G* and intersecting *DE* produced, at *H*. Make *CG′* equal to *CG* and *CH′* equal to *CH*. Then *G*,

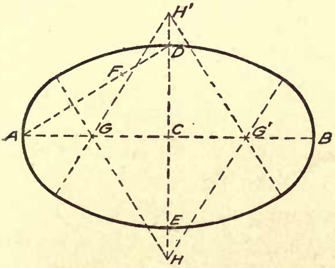


Fig. 92.

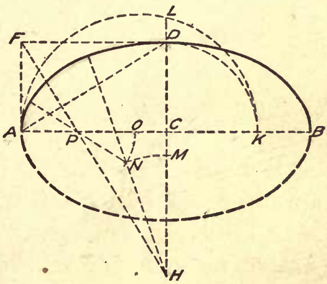


Fig. 93.

G′, *H*, and *H′* will be centers for four arcs approximating the ellipse. The half of this ellipse when used in masonry construction is known as the three-centered arch.

When a closer approximation is desired, the five-centered arch (eight-centered ellipse) may be constructed as in Fig. 93. Draw the rectangle *AFDC*, connect *AD* and draw *FH* perpendicular to it. Make *CM* equal to *DL*. With center *H* and radius *HM* draw the arc *MN*. With *A* as center and radius *CL* intersect *AB* at *O*. With *P* as center, and radius *PO* intersect the arc *MN* at *N*, then *P*, *N* and *H* are centers for one-half of the semi-ellipse or "five centered oval." This method is based on the principle that the radius of curvature at the end of the minor axis is the third proportional to the semi-minor and semi-major axes, and similarly at the end of the major axis is the third proportional to the semi-major and semi-minor axes. The intermediate radius found is the mean proportional between these two radii.

Approximate Ellipse. Fig. 94.

When the minor axis is at least two-thirds the major, the following method may be used:

Make *CF* and *CG* equal to $AB-DE$.

Make *CH* and *CI* equal to 3/4 *CF*.

F, *G*, *H*, *I* will be centers for arcs *E*, *D*, *A*, and *B*.

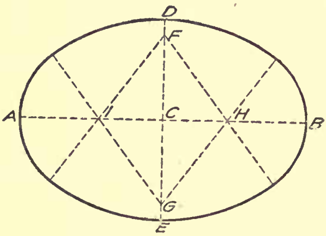


FIG. 94

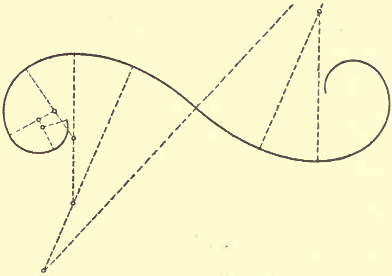


FIG. 95.—Curve inked with circle arcs.

It should be noted that an ellipse is changing its radius of curvature at every point, and that these approximations are **not** ellipses but simply curves of the same general shape.

Any non-circular curve may be approxiamted by tangent circle arcs, selecting a center by trial, drawing as much of an arc as will practically coincide with the curve, then changing the center and radius for the next portion, remembering always that

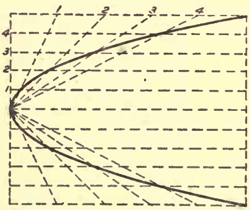


FIG. 96.—Parabola.

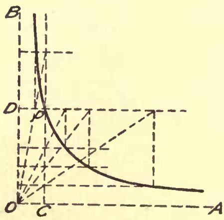


FIG. 97.—Hyperbola.

if arcs are to be tangent, their centers must lie on the common normal at the point of tangency. Many draftsmen prefer to ink curves in this way rather than to use irregular curves. Fig. 95 illustrates the construction.

A parabola may be drawn in a manner analogous to the parallelogram method of the ellipse, as shown in Fig. 96.

One of the commercial uses of the parabola is in parabolic reflectors and search lights.

The only case of the **hyperbola** of practical interest to us is the equilateral or rectangular hyperbola on its asymptotes, as representing the relation between the pressure and volume of steam or gas expanding under the law **pv** equals **c.**

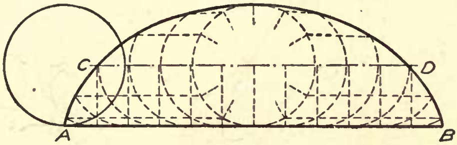


FIG. 98.—Cycloid.

To draw the rectangular hyperbola. Fig. 97.

Let *OA* and *OB* be the asymptotes and *P* a point on the curve (this might be the point of cut off on an indicator diagram). Draw *PC* and *PD*. Mark any points on *PC;* through these points draw ordinates parallel to *OA* and through the same points lines to *O*. At the intersection of these lines with *PD* draw abscissæ. The intersections of these abscissæ with the ordinates give points on the curve.

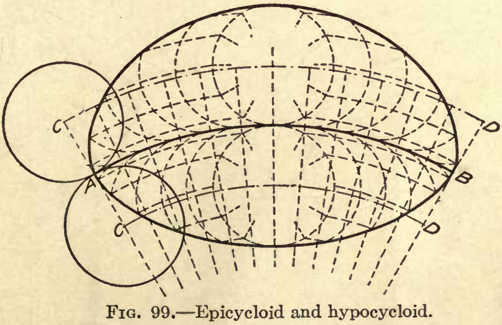


FIG. 99.—Epicycloid and hypocycloid.

A **cycloid** is the curve generated by the motion of a point on the circumference of a circle rolled along a straight line. If the circle be rolled on the outside of another circle the curve is called an **epicycloid**; when rolled inside it is called a **hypocycloid.** These curves are used in drawing gear teeth. To draw a cycloid, Fig. 98, divide the rolling circle into a convenient number of parts (say 12), lay off the rectified length of the circumference with these divisions on the tangent *AB*. Draw through *C* the line of centers *CD* and project the division points up to this line by perpendiculars. On these points as centers draw circles representing different positions of the rolling circle, and project across on these circles in order, the division points of the original circle.

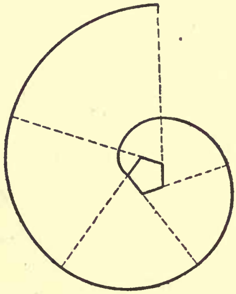


Fig. 100.—Involute of a pentagon.

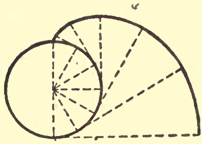


Fig. 101.—Involute of a circle.

These intersections will be points on the curve. The epicycloid and hypocycloid may be drawn similarly as illustrated in Fig. 99.

An involute is a curve generated by unwrapping an inflexible cord from around a polygon. Thus the involute of any polygon may be drawn by extending its sides, as in Fig. 100, and with the

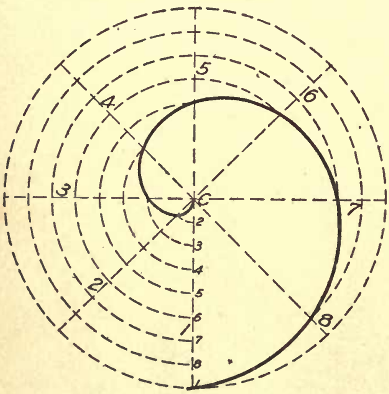


Fig. 102.

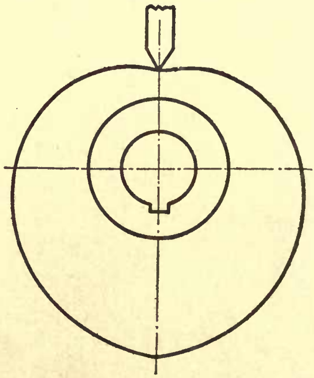


Fig. 103.

corners of the polygon as successive centers drawing the tangent arcs.

A circle may be conceived as a polygon of an infinite number of sides. Thus to draw the involute of a circle, Fig. 101, divide it into a convenient number of parts, draw tangents at these points, lay off on these tangents the rectified lengths of the arcs from the point of tangency to the starting point, and connect the points by a smooth curve. It is evident that the involute of a circle is the limiting case of the epicycloid, the rolling circle becoming of infinite diameter. It is the basis for the involute system of gearing.

To Draw the Spiral of Archimedes—making one turn in a given circle, Fig. 102.

Divide the circumference into a number of equal parts, drawing the radii and numbering the points. Divide the radius No. 1 into the same number of equal parts, numbering from the center. With *C* as center draw concentric arcs intersecting the radii of corresponding numbers, and draw a smooth curve through these intersections. This is the curve of the heart cam, Fig. 103, for converting uniform rotary motion into uniform reciprocal motion

CHAPTER V.

Lettering.

To give all the information necessary for the complete construction of a machine or structure, there must be added to the "graphical language" of lines describing its shape, the figured dimensions, notes on materials and finish, and a descriptive title, all of which must be lettered, freehand, in a style that is perfectly legible, uniform, and capable of rapid execution. So far as its appearance is concerned there is no part of a drawing so important as the lettering. A good drawing may be ruined in appearance by lettering done ignorantly or carelessly.

Lettering is **not** mechanical drawing. The persistent use by some draftsmen of kinds of mechanical caricatures known as geometrical letters, block letters, etc., made up of straight lines and ruled in with T-square and triangles, is to be condemned entirely. Lettering should be done freehand, in a style suited to the class of the drawing.* On working drawings the lettering is done in a rapid single-stroke letter, either vertical or inclined, the inclined form being preferred. The ability to letter well in this style can be acquired only by continued and careful practice, but it can be acquired by any one with normal muscular control of his fingers, who will take the trouble to observe carefully the shapes of the letters, the sequence of strokes composing them, and the rules for composition; and will practice faithfully and intelligently. It is not a matter of artistic talent, nor even of dexterity in handwriting. Many draftsmen letter well who write very poorly.

The term "single-stroke" or "one-stroke" does not mean that the entire letter is made without lifting the pen, but that the width of the stroke of the pen is the width of the stem of the letter. For the desired height, therefore, a pen must be selected

* A more complete study of the subject of lettering than is given in this chapter is necessary for draftsmen who will have any variety of work, especially civil engineers and architects, who should give particular attention to the different forms of Roman letter. Several books on the subject are mentioned in Chapter XV.

which will give the necessary width, and for what are known as "gothic" letters one which will make the same width of line when drawn horizontally, obliquely, or vertically.

The coarse pens mentioned on page 13 are particularly adapted to this purpose. Leonardt's ball point 506 F will make a line of sufficient width for letters 1/4″ high, which is as large as would be used on any ordinary working drawing. 516 EF or Gillott's 1032 might be used for letters 3/16″ high For small letters Hunt's shot point, Gillott's 1050, 604 or Spencerian No. 1 may be used. Some draftsmen prepare a new pen by dropping it in alcohol, or by holding it in a match flame for two or three seconds.

Single-stroke Vertical Caps.

The upright single-stroke "commercial gothic" letter shown in Fig. 104 is a standard for titles, reference letters, etc. In the proportion of width to height the general rule is that the smaller the letters the more extended their width should be. A low extended letter is more legible than a high compressed one and at the same time makes a better appearance. This letter is

I H L F E T N K M A V
W X Y Z 4 O Q C G D U J P
R B S 8 3 2 0 6 9 5 7 &

FIG. 104.—Upright single stroke capitals.

seldom used in compressed form. Before commencing the practice of this alphabet some time should be spent in preliminary practice to gain control of the pen. It should be held easily, in the position illustrated in Fig. 105, the strokes drawn with a steady, even motion and a slight uniform pressure on the paper, not enough to spread the nibs of the pen.

For the first practice draw in pencil top and bottom guide lines for 3/16″ letters and with a 516 F or similar pen make directly in ink a series of vertical lines, drawing the pen down with a finger movement. This one stroke must be practised until the beginner can get lines vertical and of equal weight. Remember this is drawing, not writing, and that all the flourish movements of the penman must be avoided. It may be found difficult to keep the lines vertical; if so, direction lines may be drawn, as in Fig. 105, an inch or so apart to aid the eye.

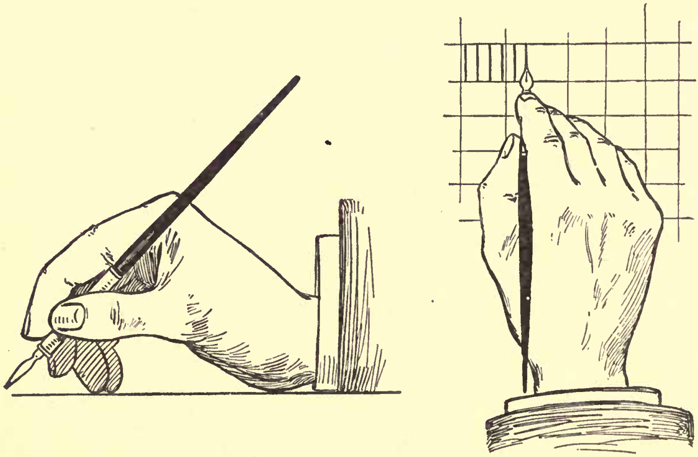


FIG. 105.—Position for lettering.

It is ruinous to the appearance of upright letters to allow them to slant forward. A slight backward slant is not so objectionable, but the aim should be to have them vertical. When this stroke

FIG. 106.—Practice strokes.

has been mastered, the succeeding strokes of Fig. 106 should be taken up. These strokes are the elements of which the single stroke letters are composed. After sufficient practice with them,

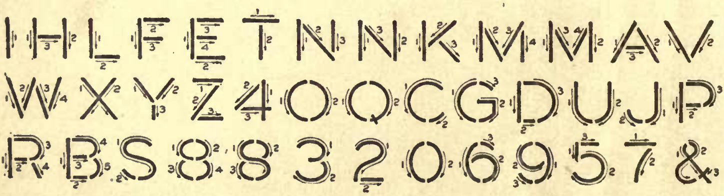


FIG. 107.—Order and direction of strokes.

they should be combined into letters in the order of Fig. 107, penciling in one pattern letter and numbering its strokes, then drawing directly in ink several beside it. Care must be taken to keep all angles and intersections clean and sharp. Getting too much ink on the pen is responsible for appearances of the kind shown in Fig. 108.

EHMNWTZ

FIG. 108.—Too much ink.

Single-stroke Inclined Caps.

The single stroke inclined letter made to a slope of between 60 and 70 degrees, Fig. 109, is preferred by perhaps a majority of draftsmen. The order and direction of strokes for the capitals of this form will be the same as in the upright form, but these letters are usually not extended. If a rectangle containing a

IHLFETNKMAV
WXYZ4OQCGDUJP
RBS83206957&

FIG. 109.—Inclined capitals.

flexible O should be inclined the curve would take the form illustrated in Fig. 110, sharp in the upper right-hand and lower left-hand corners, and stretched flat in the other two corners. This characteristic should be observed in all curved letters. A convenient and pleasing slope for these letters is in the proportion of 2 to 5, which angle may be made by laying off 2 units on the

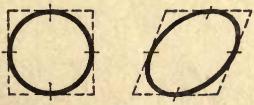


FIG. 110.

horizontal line and 5 units on the vertical line. Triangles of about this angle are sold by the dealers.

The first requirement is to learn the form and peculiarity of each of the letters. Too many persons think that lettering is simply printing in the childish way learned in the primary grades. (Fig. 111 is from actual examples of men's work.) There is an individuality in lettering often nearly as marked as in handwriting, but it must be based on a careful regard for the fundamental letter forms.

In our practice we must first learn the individual letters, then compose them into words and groups of words. The inclined letter is used in capitals for titles and headings, and in capitals

Fig. 111.—Inexcusable faults.

and small letters for less important captions, and for notes and descriptions. In all lettering there should always be drawn guide lines for both the tops and bottoms. In the inclined style the 2 to 5 direction lines should be drawn until one has become very proficient in keeping the lines to a uniform slant. The snap and swing of professional work is due largely to two things;

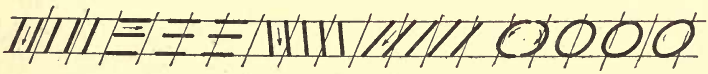


Fig. 112.—Practice strokes.

keeping the letters full, and close together, and of uniform slope. The beginner's invariable mistake is to cramp the letters and space them too far apart.

It will be noticed that the letters are arranged in family groups instead of in the usual alphabetical order. After practising a few preliminary strokes Fig. 112, the letters should be taken up

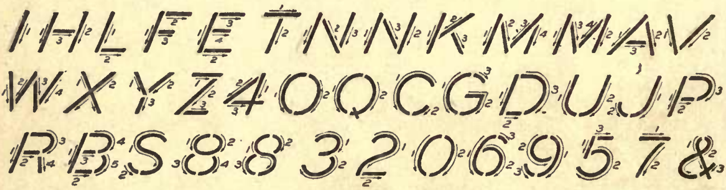


Fig. 113.—Order and direction of strokes.

in the order given in Fig. 113, and each one practised. The rule of stability requires that such letters as B, E, K, S, X, Z, with the figures 3 and 8 be smaller on the top than on the bottom, and that the cross lines in E, F, H, be slightly above the middle. The bridge of the A is up about 1/3 of the height. Particular care should be given to the accurate formation of numerals, making them round and full bodied and of the same height as the capitals.

Single-stroke Inclined Lower Case.

The lower case or small letters of this style are drawn with bodies two-thirds the height of the capitals. This letter is

Fig. 114.—Basis of Reinhardt letter.

generally known as the Reinhardt letter, in honor of Mr. Charles W. Reinhardt, Chief of the Drafting Department of the "Engineering News," who has used it so successfully in the illustrations for that periodical, and who published it as a system in his admirable little book "Lettering for Engineers." It is the minuscule or lower case letter reduced to its lowest terms, omitting all unnecessary hooks and appendages. It is very legible and

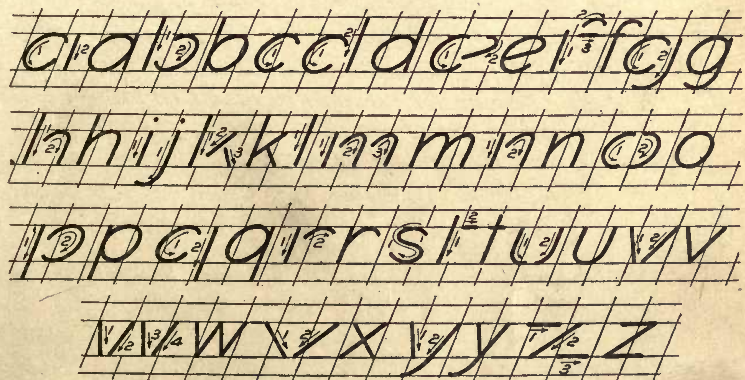


Fig. 115.—Analysis of Reinhardt letter.

effective, and after its swing has been mastered can be made very rapidly. This lower case letter should be used in all notes and statements on drawings, for the two reasons given above, it is read much more easily than all capitals, as we read words by their shapes and are familiar with these shapes in the lower case letters; and it can be done fast.

All the letters of this alphabet are based on two strokes, the straight line, and the partial ellipse whose conjugate axes are the slope line and the horizontal line, and consequently whose major axis is about 45°, Fig. 114. The general direction of strokes is always downward or from left to right, and in the order given in the analyzed letters in Fig. 115.

In the composition of letters into words three general rules must be remembered. 1, Keep the letters close together; 2, have the areas of white spaces, the back grounds between the letters, approximately equal; 3, keep words well separated, to a space at least equal to the height of the letter. Paragraphs are always indented. Fig. 116 is an example of spacing of letters, words, and lines.

As soon as the letter forms have been mastered all the practice should be directed to composition, which is fully as important as the individual shapes. Titles on working drawings are usually boxed in the lower right hand corner. The question of dimensioning and the contents of the title are fully discussed in Chapter IX on working drawings.

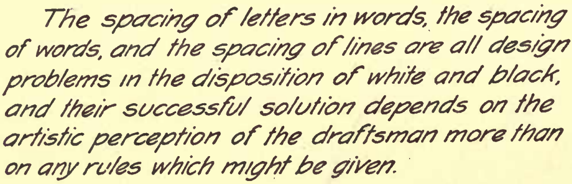


FIG. 116.—Composition.

CHAPTER VI.

Orthographic Projection.

The previous chapters have been preparatory to the real subject of engineering drawing as a language. In Chapter I was pointed out the difference between the representation of an object by the artist to convey certain impressions or emotions, and the representation by the engineer to convey information.

If an ordinary object be looked at from some particular station point, one may usually get a good idea of its shape, because (1) generally more than one side is seen, (2) the light and shadow on it tell something of its configuration, (3) looked at with both

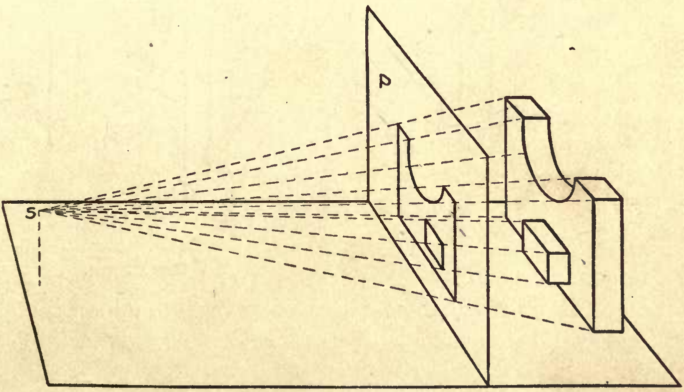


Fig. 117.—Perspective projection.

eyes there is a stereoscopic effect to aid in judging dimensions. In technical drawing the third point is never considered, but the object is drawn as if seen with one eye; and only in special cases is the effect of light and shadow rendered. In general we have to do with outline alone.

If a transparent plane *P*, Fig. 117, be imagined as set up between the object and the station point *S* of the observer's eye, the intersection with this plane, of the cone of rays formed by lines from the eye to all points of the object, will give a picture of the object, which will be practically the same as the picture formed on the retina of the eye by the intersection of the other end (nappe) of the cone.

Drawing made on this principle is known as perspective drawing and is the basis of all the artist's work. In a technical way it is used chiefly by architects in making preliminary sketches for their own use in studying problems in design, and for showing their clients the finished appearance of a proposed building. It is entirely unsuited for working drawings, as it shows the object as it appears and not as it really is. In this book we shall take up

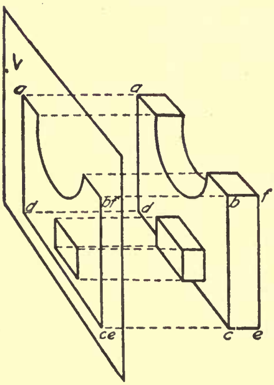


FIG. 118.—Orthographic projection.

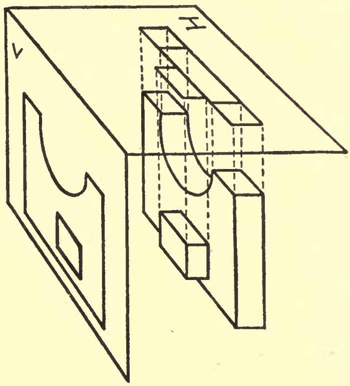


FIG. 119.—The *H* plane.

only the general principles of perspective as applied in freehand sketching, Chapter X. The titles of several books which explain in detail the methods of perspective are given in Chapter XV.

Orthographic Projection.

The problem in engineering drawing is to represent accurately on the paper having only two dimensions, length and breadth, the three dimensions of the structure.*

* The whole subject of graphic representation of solids on reference planes comes under the general name of descriptive geometry. That term, however, has by common acceptance been restricted to a somewhat more theoretical treatment of the subject as a branch of mathematics. This book may be considered as an ample preparation for that fascinating subject, with whose aid many difficult problems may be solved graphically.

If the station point *S* be conceived as moved back theoretically to an infinite distance, the cone of rays would become a cylinder with its elements perpendicular to the picture plane *V*, Fig. 118, and its intersection with it will give a picture known as the

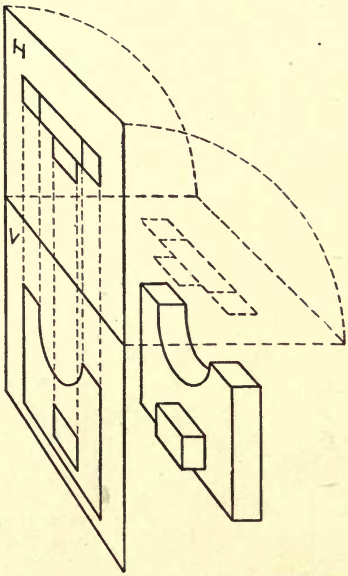


Fig. 120.—The *H* plane revolved.

orthographic projection. If we then discard the part of the cylinder between the picture plane and the eye we may say that the orthographic projection of an object on a plane would be found by dropping perpendiculars from the object to the plane.

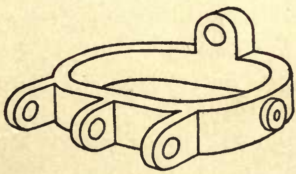


Fig. 121.

Evidently, then, a line or surface of the object parallel to the plane would be shown in its true size (**abcd**), a line perpendicular would be projected as a point (**ce**), and a plane surface perpendicular to the picture plane would be projected as a line (**bcef**). Thus the height and width of the object would be shown on the projection in their true size.

If now another plane be placed horizontally above the object and perpendicular to the first plane, Fig. 119, the projection on this plane will give its appearance as if viewed from directly above, showing its width and thickness. If this plane be revolved about its intersection with the first plane until they

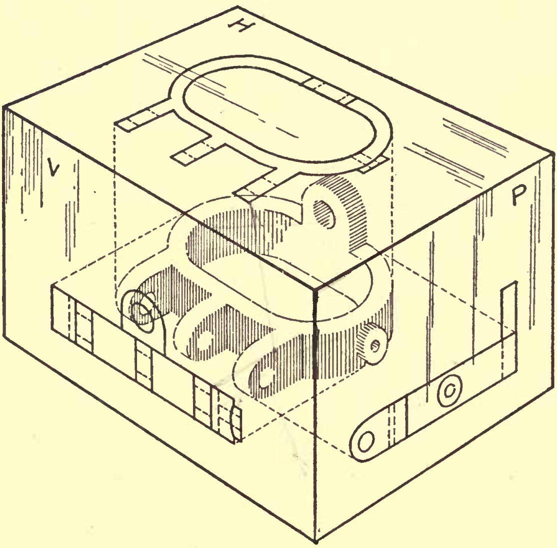


FIG. 122.—"The transparent box."

coincide, Fig. 120, they will represent the plane of the paper and the two views together will show exactly the three dimensions of the object. Similarly any other side may be represented by imagining it to be projected to a plane and the plane afterward revolved away from the object into the plane of the paper.

Thus the object, Fig. 121, may be thought of as surrounded by a box with transparent sides, Fig. 122. The projections on these sides would be practically what would be seen by looking straight at the object from positions directly in front, above, and at both sides. These "planes of projection" when revolved into one plane, Fig. 123, and represented on the paper as in Fig. 124 give what are known as the different "views" of the object. The projection on the front or vertical plane is known as the front

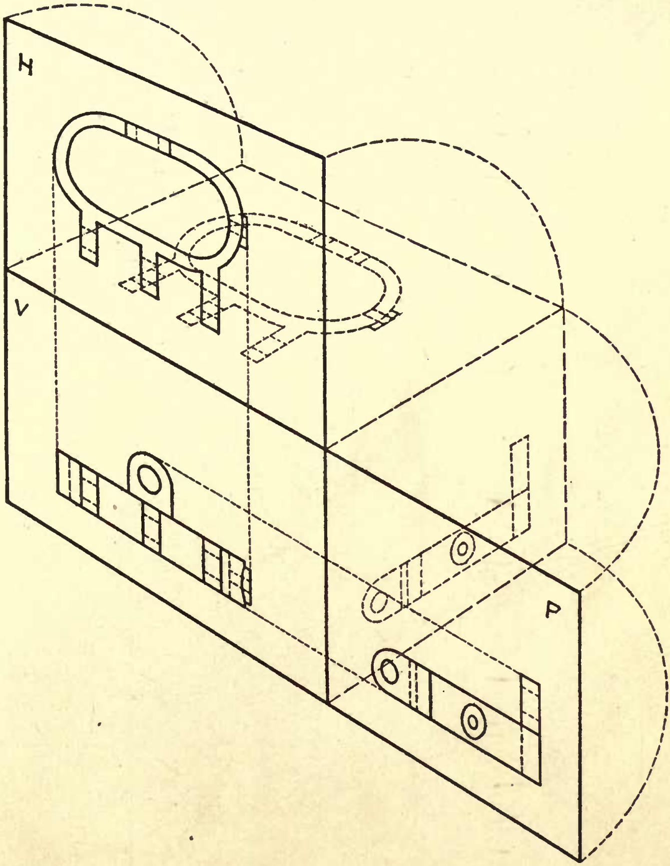


FIG. 123.—The box opened.

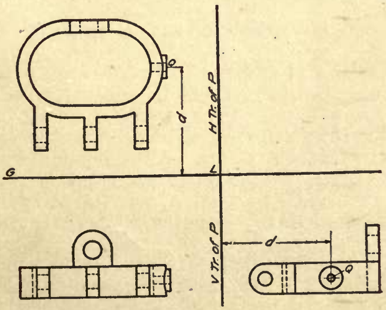


FIG. 124.—The three projections.

view, vertical projection, or front elevation; that on the horizontal plane as the top view, horizontal projection, or plan; that on the side or profile plane as the side view, profile projection, or side elevation. When necessary the bottom view and back view may be made in a similar way, by projecting to their planes and opening them up to coincide with the vertical plane.

Three principles are evident, first, the top view is directly over the front view, second, the side views are in the same horizontal line as the front view, third, the width of the side views are exactly the same as the width of the top view. For brevity we shall call the vertical plane *V*, the horizontal plane *H* and the profile plane *P*. The intersection of *H* and *V* is called the ground line, *GL*, and the intersections of *P* with *H* and *V* called the *H* trace of *P*, and the *V* trace of *P*. *P* is generally revolved about its *V* trace as in the illustration in Fig. 124, but may be revolved about its *H* trace as in Fig. 126. Evidently the side view of any point as *Q* would be as far from the *V* trace of *P* as its top view is from the ground line.

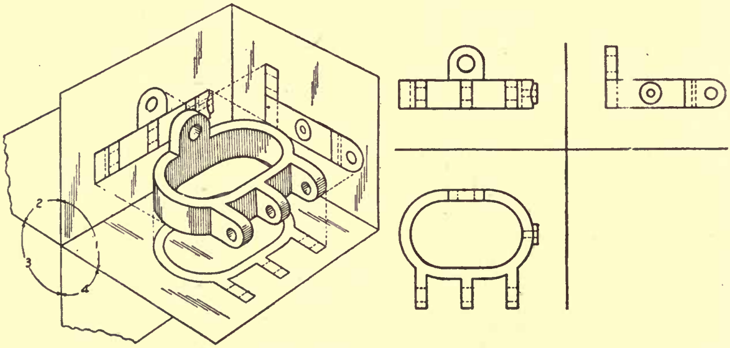


FIG. 125.—First angle projection.

Note. If the horizontal and vertical planes are extended beyond their intersection, four dihedral angles will be formed, which are numbered as illustrated in Fig. 125. If the object be placed in the first angle, projected to the planes and the planes opened as before, the top view would evidently fall below the front view, and if the profile plane were added the view of the left side of the figure would be to the right of the front view. This system, known as first angle projection, was formerly in universal use, but was generally abandoned in this country more than twenty years ago and is now almost obsolete. The student should understand it, however, as it may be encountered occasionally in old drawings, in some book illustrations, and in foreign drawings. In England some attempt is being made to introduce true (third angle) projection, but as yet it has not been accepted to any extent.

The monument Fig. 127 is shown in orthographic projection in Fig. 128. On the top view the *H* tr. of *P* is *OA*. Evidently in the revolution of *P* about its *V* tr., the *H* tr. would revolve to *OB* and the points projected to it from the top view would revolve with it. These, if projected down from *OB* to meet hori-

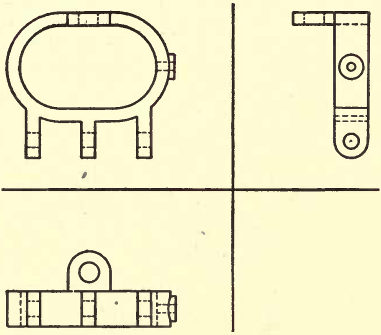


Fig. 126.

zontal projectors from corresponding points on the front view, would locate the points on the side view. Fig. 129 illustrates the principle pictorially.

In practice only as many views are made as are necessary to describe the object, and the ground line and *P* traces are not

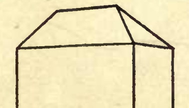


Fig. 127.

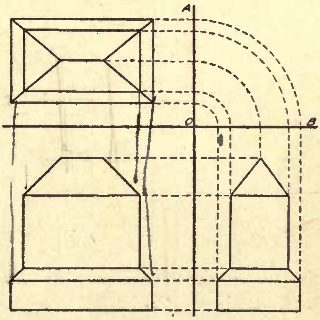


Fig. 128.

represented, but center lines or other lines of the views are used for reference or datum lines as in Fig. 130. Thus the center line of the side view may be regarded as the edge of a reference plane whose *H* trace is the center line on the top view. In our theoretical study we shall make the three views of a number of simple objects, at first working from the *GL* and *V* trace of *P* as datum lines, afterward using center lines; developing the ability to write the language, and exercising the imagination in seeing the object itself in space by reading the three projections.

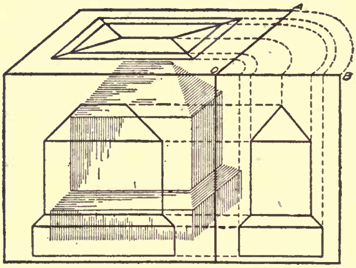


Fig. 129.

Fig. 131 shows successive cuts made on a block, and the corresponding projections of the block in the different stages. The effort should be made to visualize the object from these projections until the projection can be read as easily as the picture. A drawing as simple as *A′* or *B′* can be read, and the mental

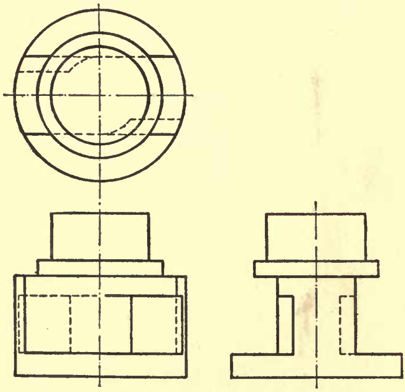


Fig. 130.

picture formed, at a glance; one with more lines as *E′* will require a little time for study and comparison of the different views. One cannot expect to read a whole drawing at once any more than he would think of reading a whole page of print at a glance.

Fig. 132 is another progressive series, illustrating the necessary use of hidden lines.

The objects in Fig. 133 are to be "written" in orthographic

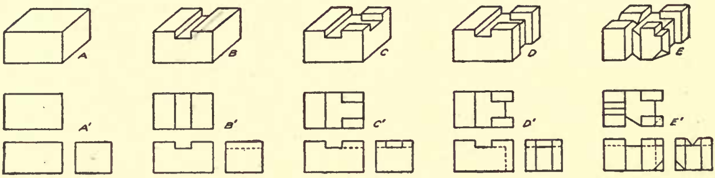


FIG. 131.

projection by sketching their three views. Similar practice may be gained by sketching the projections of any simple models,

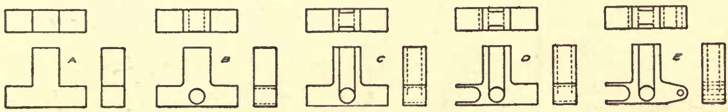


FIG. 132.

or objects with geometrical outlines, such as those illustrated in Fig. 390.

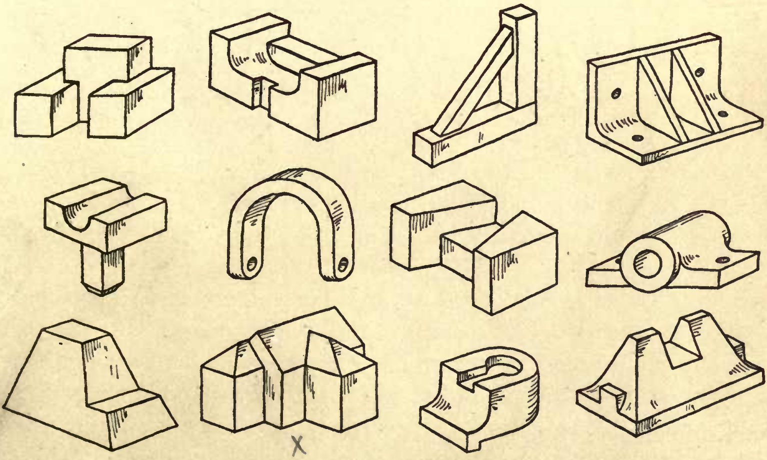


FIG. 133.

After a study of the methods of pictorial representation (Chapter VIII) we shall reverse this operation and practise reading, by making the pictures of objects drawn in orthographic projection.

Auxiliary Views.

Sometimes a view taken from another direction will aid in showing the shape or construction of an object to better advantage than can be done on the three reference planes alone, and often such a view may save making one or more of the regular views. For example, the three views of Fig. 134 do not show the face *A* clearly. A projection on a plane whose edge (*H* trace) is *S-S*, parallel to the face *A*, Fig. 135, would show the true size of the face, and the position of the hole, and would obviate the necessity for a side view. The projection is imagined as made by dropping perpendiculars to the plane, and revolving the plane about *S-S*

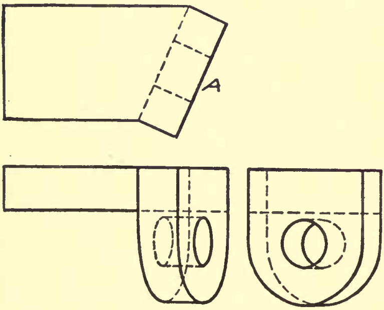


FIG. 134.

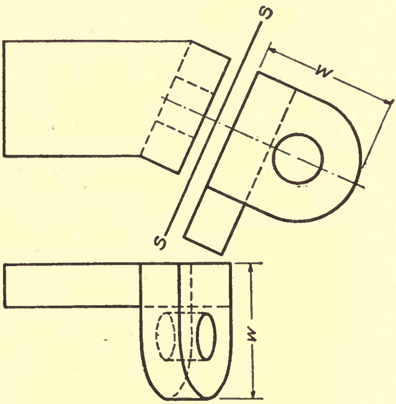


FIG. 135.—Auxiliary projection.

into the plane of the top view, as illustrated pictorially in Fig. 136. Since this plane is perpendicular to *H*, the width *W* of this view would evidently be the same as the width of the front view.

Such a plane as *S* is called an auxiliary plane, and the projection on it an auxiliary projection or auxiliary view.

These planes may be set up anywhere perpendicular to one of the planes of projection, and revolved into the plane of the paper. In practical work extensive use is made of auxiliary views in showing the true size of sections and inclined surfaces.

The plane *S* in Fig. 136 was taken perpendicular to *H* and revolved into *H*. It might as readily have been revolved about its *V* trace into *V*. Fig. 137 is the picture of an object with the *H* and *V* planes, and an auxiliary plane parallel to one of the

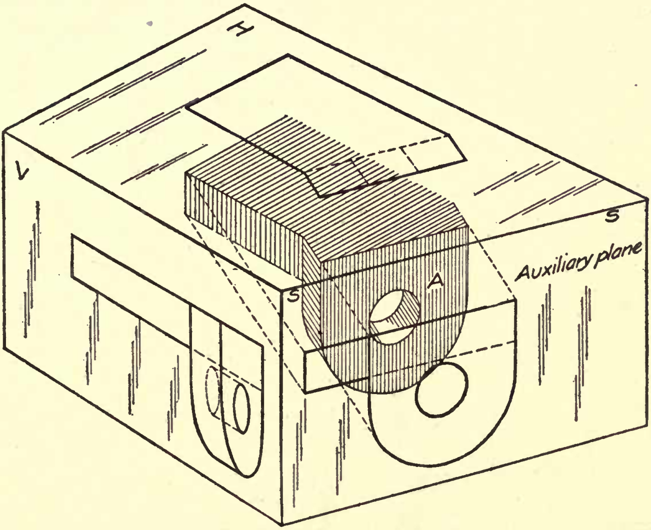


FIG. 136.

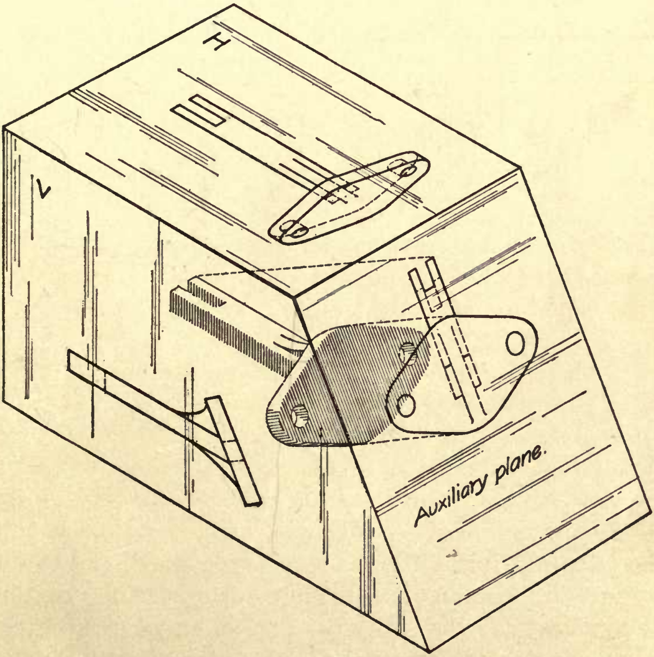


FIG. 137.

faces of the object and perpendicular to V. Fig. 138 shows the position of the planes and the projections when opened up, the auxiliary plane being revolved about its V trace to coincide

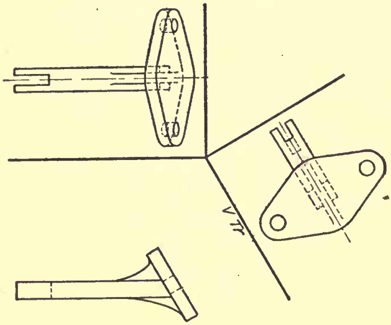


FIG. 138.—Auxiliary projection.

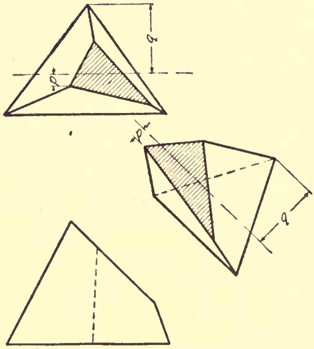


FIG. 139.—Auxiliary projection.

with V. These figures illustrate clearly that the dimensions of the auxiliary view are obtainable directly from the other views.

In practice the auxiliary plane trace is not actually drawn, but, like the ground line, after use has been made of it in explain-

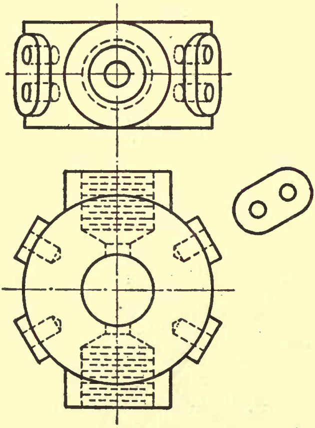


FIG. 140.

ing the principle, its position is simply imagined, and the views are worked from center lines. Thus in Fig. 139 the center line on the auxiliary view is really the projection of the center line of the top view or, more accurately, the edge of a plane whose H

trace is the center line of the top view, and the perpendicular distance of any point as **p** or **q** from the center line on the top view is laid off perpendicular to the center line on the auxiliary view.

Often it is not necessary to project the whole figure on the auxiliary plane, but only the part to be shown in true shape, as the lug or pad in Fig. 140 or the cut face of Fig. 141.

An auxiliary plane may be imagined as detached from its trace and may be set off anywhere at a convenient place on the paper.

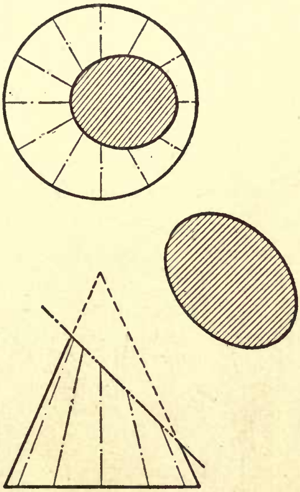


Fig. 141.

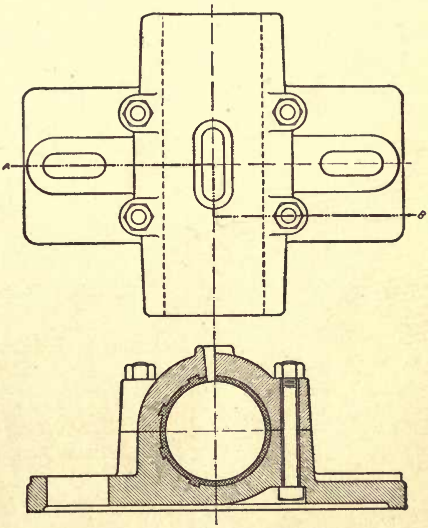


Fig. 142.—Section on *A-B*.

Sectional Views.

Often it is not possible to show clearly the interior construction or arrangement of an object by outside views, using dotted lines for the invisible parts. In such case the object is drawn as if a part of it were cut or broken away and removed. A projection of this kind is known as a sectional view, or section, and the exposed cut surface of the material is indicated by "section lining." It should be understood that in thus removing an obstructing portion so as to show the interior on one view, the same portion is not removed from the other views; but on the view to which the cut surface is perpendicular the trace of the cutting plane is indicated by a line. Thus in Fig. 142 the top view shows the trace of the cutting plane *A-B*, and the front view is a section

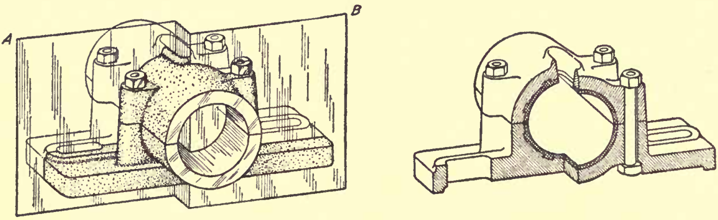


FIG. 143.

showing the bearing as it would appear if the part in front of the plane *A-B* were removed. Fig. 143 is a pictorial illustration. This figure also illustrates the fact that the cutting plane need not

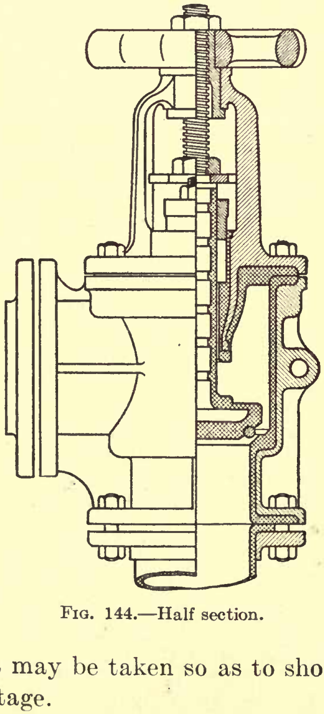


FIG. 144.—Half section.

be continuous, but may be taken so as to show the construction to the best advantage.

When a figure is symmetrical about an axis, it is a common practice to show half in section and the other half in full. Figs. 144 and 145 are examples. Fig. 146, an illustration of a broken section, is self-explanatory.

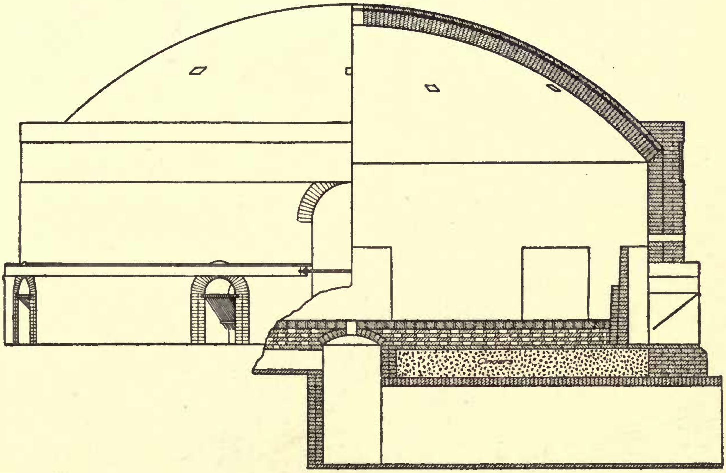


FIG. 145.—Half section.

Little auxiliary views known as turned sections, or revolved sections, are of great convenience in showing the shape of some particular part. They may be drawn directly on the view, as

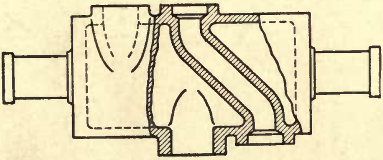


FIG. 146.—Broken section.

in Fig. 147, or the piece may be broken to admit of placing the section, as in Fig. 148.

It is not assumed that the cutting plane cuts everything

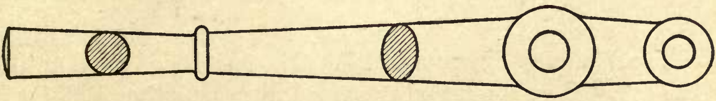


FIG. 147.—Revolved sections.

through which it passes. It is a practical rule in drawing that if in a sectional view a part can be shown more clearly by leaving it in position full, it is so left. This is true of shafts, bolts, rods, keys, etc., which are never sectioned, but are drawn as in Figs. 149 and 150. A combination full and sectional view, known as a "dotted section" will sometimes show the construction of an object economically. Fig. 151 *A* is an illustration.

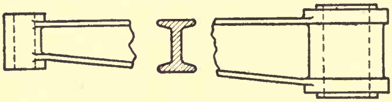


FIG. 148.—Revolved section.

Section lining is done with a fine line, generally at 45 degrees, and spaced uniformly, to give an even tint, the spacing being governed by the size of the surface, but except in very small drawings not less than 1/16 of an inch. On drawings to be inked or traced the section lining is only indicated freehand in

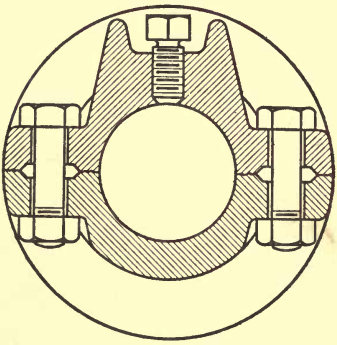


FIG. 149.

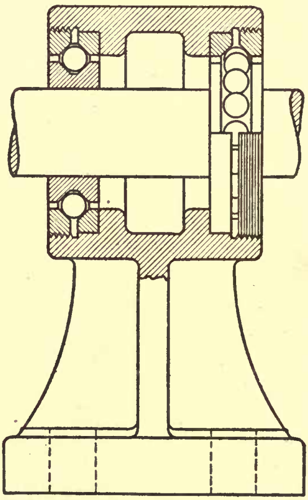


FIG. 150.

pencil, and is done directly in ink. The spacing is done entirely by the eye. Care should be exercised in setting the pitch by the first two or three lines, and one should glance back at the first lines often in order that the pitch may not gradually change to wider or narrower.

Large surfaces in section are sometimes shown as in Fig. 152. This both saves time and improves the appearance. Adjacent pieces are section lined in opposite directions, and are often

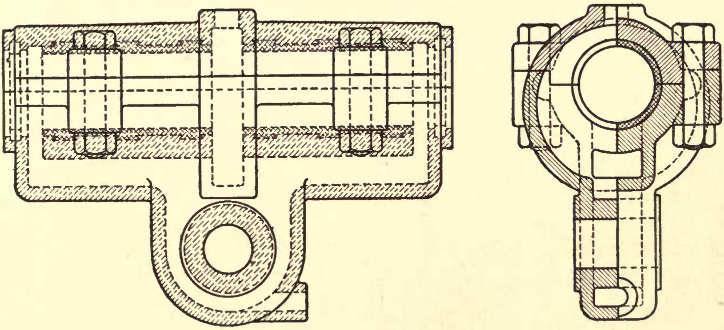


FIG. 151.—A dotted section.

brought out more clearly by varying the pitch, using lines closer together for smaller pieces.

Different materials are sometimes indicated by conventional symbols. The use of those symbols is discussed in Chapter IX.

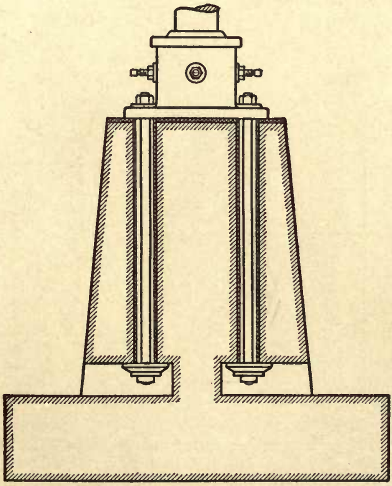


FIG. 152.

Revolution.

The natural way to place an object would be in the simplest position, with one face or edge parallel to a plane of projection.

It is sometimes necessary, however, to represent it in a position oblique to the planes. In such a case it may be necessary to draw the object first in a simpler position, and revolve it about an axis perpendicular to a plane of projection to the required position.

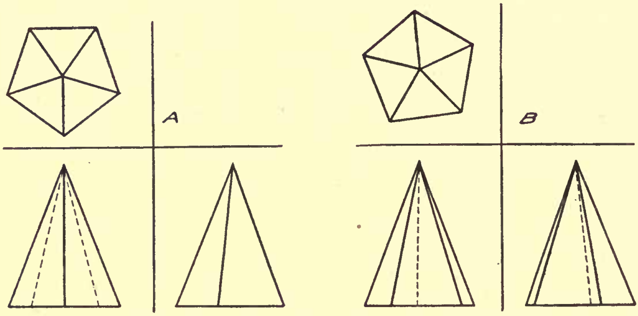


FIG. 153.—Revolution about axis perpendicular to *H*.

Rule: If an object be revolved about an axis perpendicular to a plane, its projection on that plane will remain unchanged in size and shape, and the dimensions parallel to this axis on other planes will be unchanged.

Thus if the pyramid Fig. 153 be revolved through 30 degrees about an axis perpendicular to the *H* plane, its *H* projection will take the

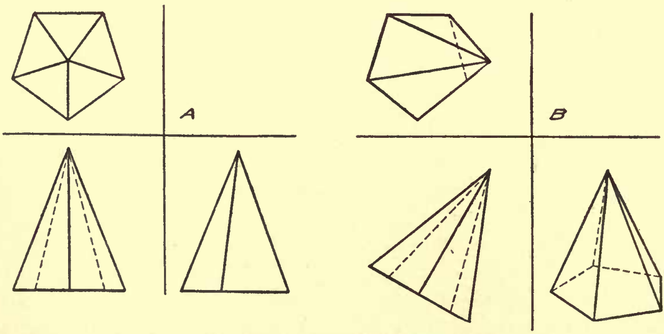


FIG. 154.—Revolution about axis perpendicular to *V*.

position shown at *B*. The height of the pyramid has not been changed in the revolution, hence the front and side views are the same height as the original front view. If, instead, the pyramid be revolved about an axis perpendicular to *V*, the front view will be unchanged and may be copied in the new position. The distance from the ground line to any point in the top view would be unchanged, hence the new top view may be found by projecting up from the front view and across from the original top view, Fig. 154.

Similarly in the revolution forward or back, about an axis perpendicular to *P*, the side view is unchanged and the dimensions (widths) on the top and front are the same as in the original position, Fig. 155.

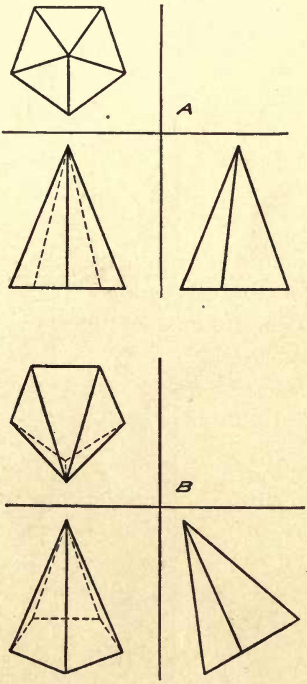


Fig. 155.—Revolution about axis perpendicular to *P*.

Successive revolutions may be made under the same rules. Fig. 156 is a block revolved from its first position about an axis perpendicular to *H* through 45 degees, then about an axis perpendicular to *P* through 45 degrees until the cut face *MNO* is parallel to the vertical plane. To avoid confusion it is well to letter or number the corresponding points as the views are carried along.

Evidently the only difference in principle between revolutions and auxiliary planes is that in the former the object is moved and in the latter the plane is moved.

Although objects in practical drawing would never be placed in these complicated positions, unless unavoidable, problems in revolution are an excellent aid in the understanding of the theory of projection.

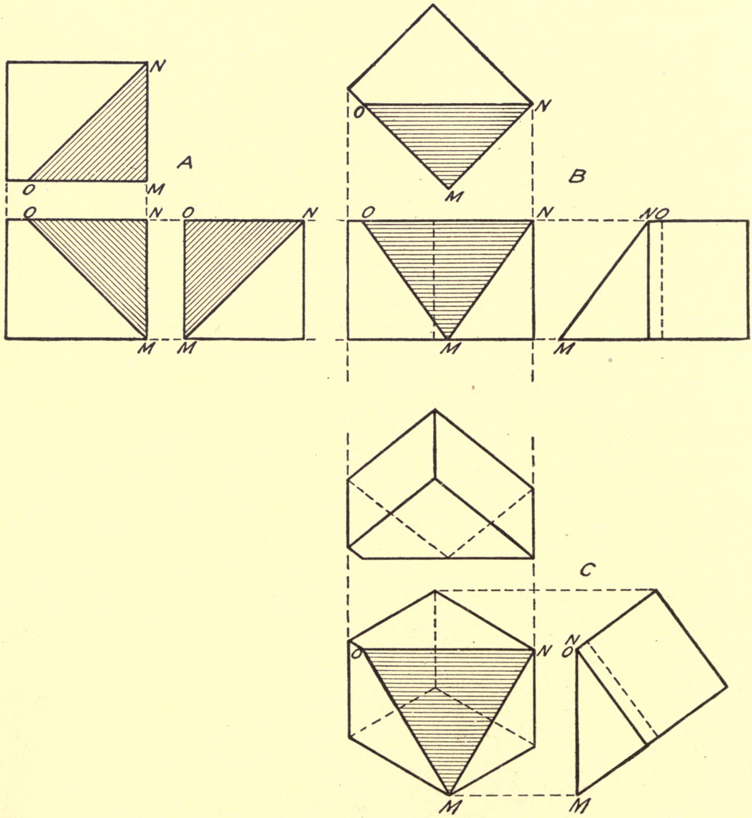


Fig. 156.—Successive revolutions.

The True Length of a Line.

These principles are evident: If a line is parallel to a plane its projection on that plane will be equal in length to the line itself.

If a line is perpendicular to a plane its projection on the plane will be a point.

If a line is inclined to a plane its projection will be shorter than the line.

If a line is parallel to H or V its projection on the other plane will be parallel to the ground line.

A line inclined to both H and V will not show its true length

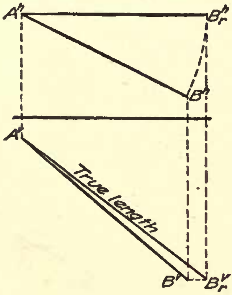


Fig. 157.

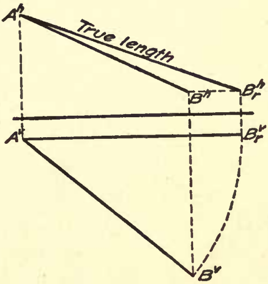


Fig. 158.

in either projection. If it be revolved until it is parallel to one of the planes its projection on that plane will be its true length. In Fig. 157 the line AB is revolved about an axis perpendicular to H until it is parallel to V and its true length is $A^vB^v{}_r$. Fig. 158 is a similar construction with the axis perpendicular to V.

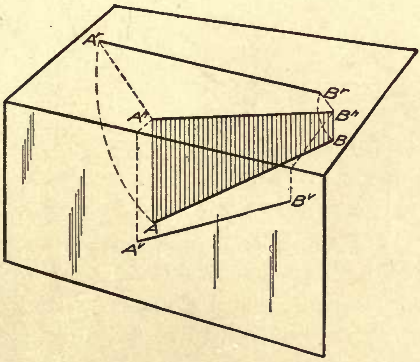


Fig. 159.

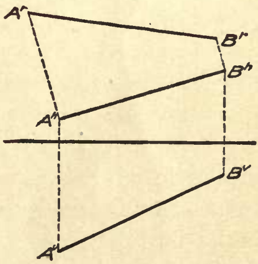


Fig. 160.

Or by a second method the line may be revolved about its projection, into the plane. This is illustrated pictorially in Fig. 159. The H projection of the line AB in space is a line connecting the feet of all the perpendiculars from AB to the plane. These perpendiculars form what is known as the projecting plane.

If this projecting plane be revolved about its H trace, which is the H projection of the line, until it coincides with H, the line will be seen in its true length.

Construction. Fig. 160. The distance of A and B below H is indicated on the V projection. Thus if to A^h B^h the perpendiculars A^h A^r and B^h B^r be drawn, A^r B^r will be the true length of AB.

Shade Lines.

In the alphabet of lines the visible outline was indicated as a uniform, bold, full line. This is the general practice for working drawings.

It is possible by using two weights of lines, to add something to the clearness and legibility of a drawing, and at the same

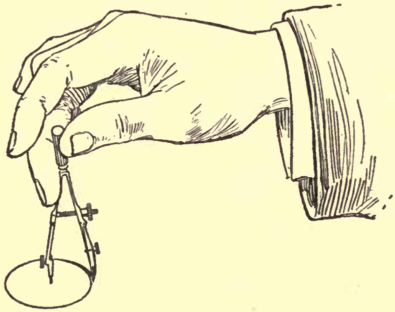


FIG. 161.—Shading a circle.

time to give to its appearance a relief and finish very effective and desirable in some classes of work. Shade lines are required on patent office drawings, and are used in a few shops on assembly drawings, but for ordinary shop drawings the advantage gained is overbalanced by the increased cost. It is correct to use them whenever the gain in legibility and appearance is of sufficient importance to warrant the expenditure of the added time necessary.

Theoretically the shade line system is based on the principle that the object is illuminated from one source of light at an infinite distance, the rays coming from the left in the direction of the body diagonal of a cube, so that the two projections of any ray each make an angle of 45 degrees with the GL. Part of the object would thus be illuminated and part in shade, and a shade line is a line separating a light face from a dark face. The strict application of this theory would involve some trouble, and it is never done in practice, but the simple rule is followed of shading the lower and right hand lines of all figures.

The light lines should be comparatively fine and the shade lines about three times their width. The width of the shade line is added outside the surface of the piece. They are never drawn in pencil, but their location may be indicated, if desired, by a mark on the line. In inking a shaded drawing all light lines alone should be inked first, then the shade lines.

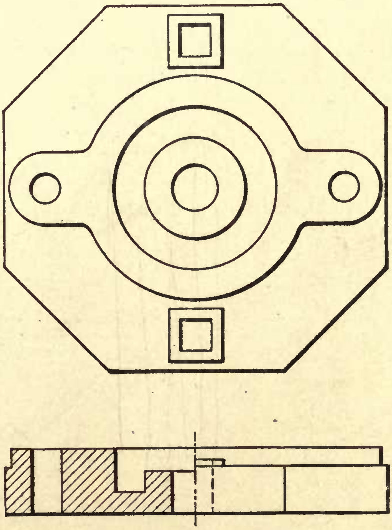


Fig. 162.—Shade lines.

A circle may be shaded by shifting the center on a 45-degree line toward the lower right hand corner, to an amount equal to the thickness of the shade line, and drawing another semicircular arc with the same radius, or it may be done much more quickly, particularly with small circles, after the "knack" has been acquired, by keeping the needle in the center after drawing the circle and springing the compass out and back gradually by pressing with the middle finger in the position of Fig. 161. Never shade a circle arc heavier than the straight lines.

Fig. 162 is an example of a shade line drawing. The aid in reading given by the shade lines will be noted.

Line shading is a method of representing the effect of light and shade by ruled lines, used on patent drawings, "show plans," drawings for illustration, and the like. To execute it effectively

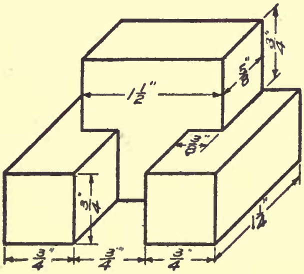


FIG. 163.

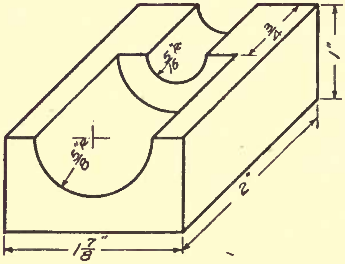


FIG. 164.

and rapidly requires practice and is an accomplishment not usual among ordinary draftsmen. An explanation of the methods, and several examples illustrating its application are given in Chapter XIV, page 259.

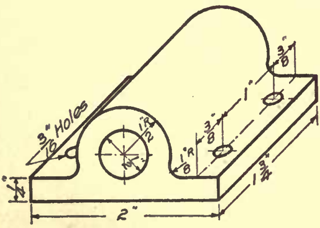


FIG. 165.

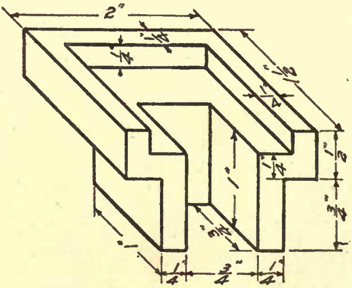


FIG. 166.

PROBLEMS.

If drawn to the dimensions and scales given, these problems will each occupy a space not to exceed 4″ x 5″.

Group I.—Orthographic from pictorial views.

Prob. 1. Draw three views of block, Fig. 163, using *G.L.*

2. Draw three views of core box, Fig. 164, using center lines (without *G.L.*).

3. Draw three views of box, Fig. 165, using center lines.
4. Draw three views of block, Fig. 166, using *G.L.*
5. Draw three views of support, Fig. 167, using center lines.
6. Draw three views of block, Fig. 168, using *G.L.*

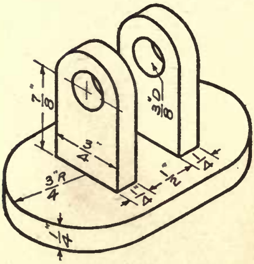


Fig. 167.

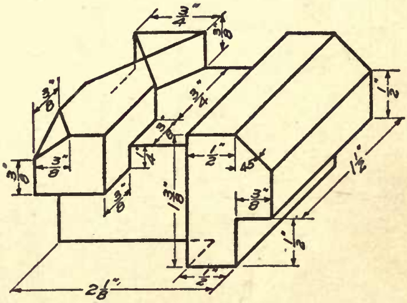


Fig. 168.

7. Draw three views of block, Fig. 169, using *G.L.*
8. Draw three views of piece, Fig. 170, using center lines.

When three views are specified, the top view, front view, and right side view are understood.

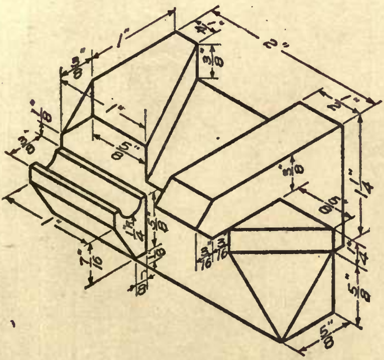


Fig. 169.

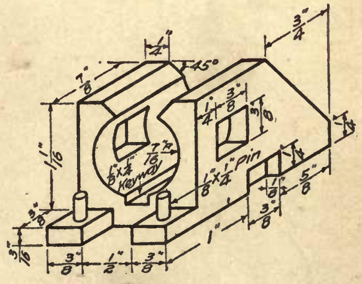


Fig. 170.

Group II.—Views to be completed.

Prob. 9. Draw the top and front views given, Fig. 171, and add side view. Scale 6″ = 1 ft.

10. Draw three views of clamp, Fig. 172. Scale 6″ = 1 ft.

11. Complete the top and front views and draw side view of block, Fig. 173. Scale 3″ = 1 ft.

12. Draw three views of block, Fig. 174. Scale 3″ = 1 ft.

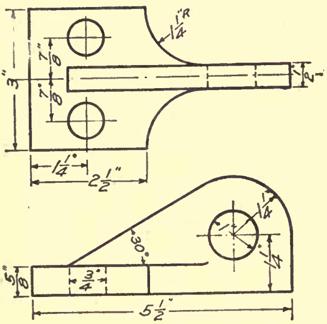


Fig. 171.

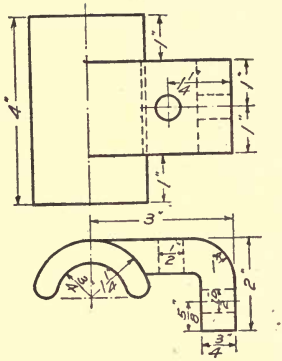


Fig. 172.

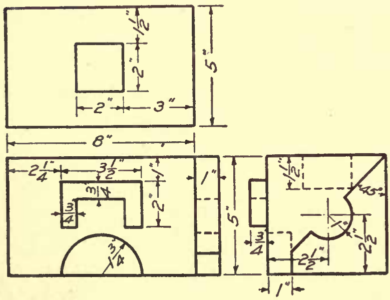


Fig. 173.

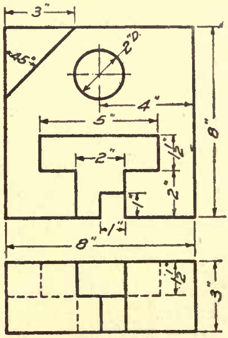


Fig. 174.

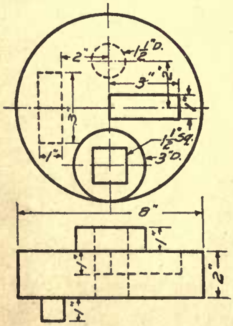


Fig. 175.

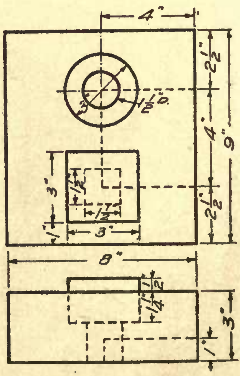


Fig. 176.

13. Draw three views of circular block, Fig. 175. Scale 3″=1 ft.

14. Draw three views of block, Fig. 176. Scale 3″=1 ft.

For further practice the bottom and left side views of problems 12, 13, and 14 may be drawn.

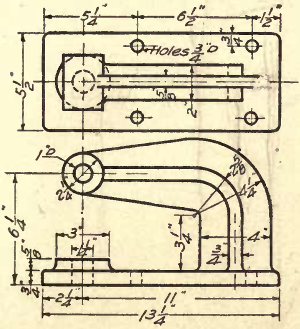


Fig. 177.

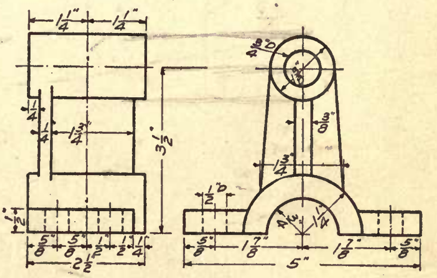


Fig. 178.

15. Draw front view, complete top view, and draw left side view of frame, Fig. 177. Scale 3″=1 ft.

16. Draw front view, top view, and complete left side view given, of the standard, Fig. 178. Scale 6″=1 ft.

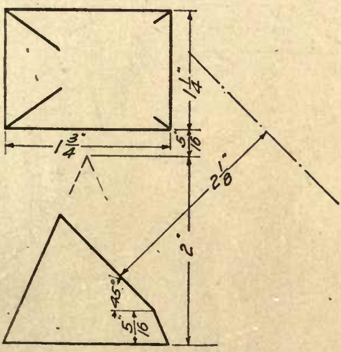


Fig. 179.

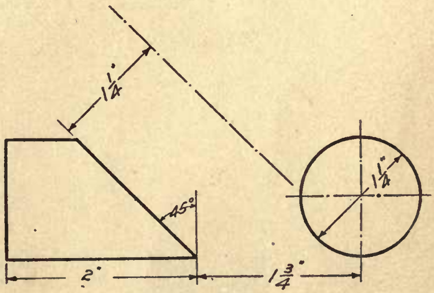


Fig. 180.

Group III.—Auxiliary projections.

Prob. 17. Draw the front view given, complete the top view and draw auxiliary view on the given *C.L.* of truncated pyramid, Fig. 179. Full size.

18. Draw auxiliary view of cylinder, Fig. 180.

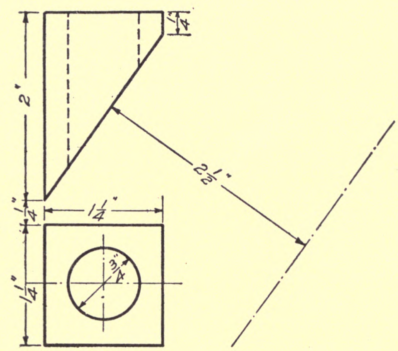


FIG. 181.

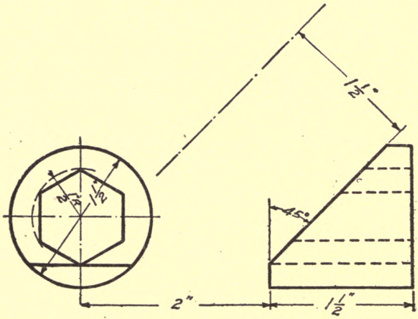


FIG. 182.

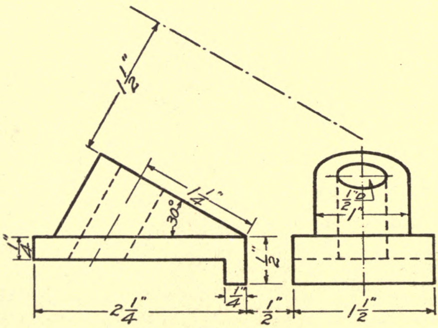


FIG. 183.

19. Draw auxiliary view of square prism, Fig. 181.
20. Draw auxiliary view of cylinder, Fig. 182.
21. Draw auxiliary view of block, Fig. 183.

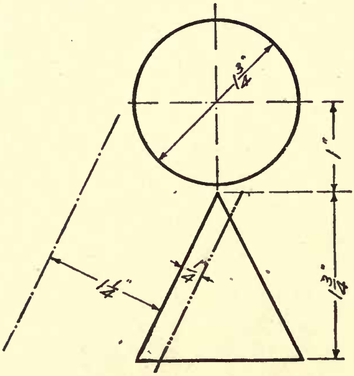


FIG. 184.

22. Draw auxiliary view of cone cut by plane, Fig. 184.
23. Draw auxiliary view of pentagonal pyramid, Fig. 185.
24. Draw auxiliary view of bearing, Fig. 186. Scale 3″ = 1 ft.

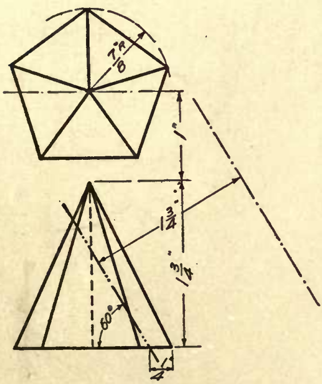


FIG. 185.

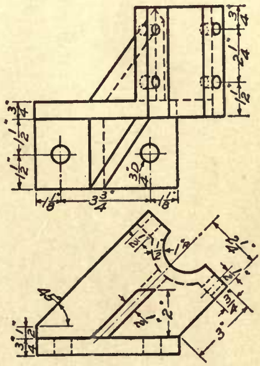


FIG. 186.

Group IV.—Sectional views.

Prob. 25. Draw front view and sectional side view of ring, Fig. 187. Full size.

26. Draw front view and sectional top view of eccentric, Fig. 188. Scale 6″ = 1 ft.

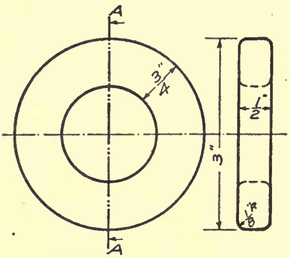


FIG. 187.

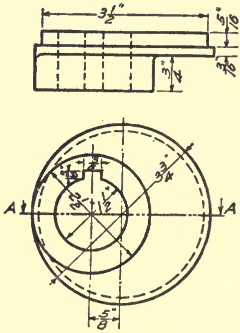


FIG. 188.

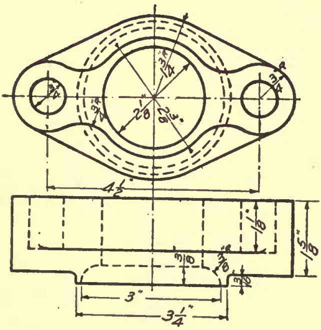


FIG. 189.

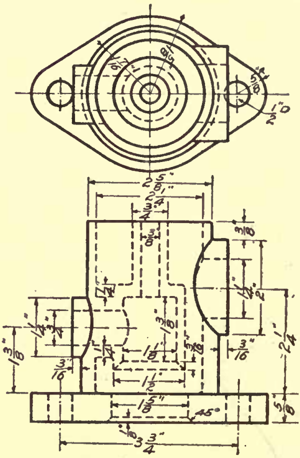


FIG. 190.

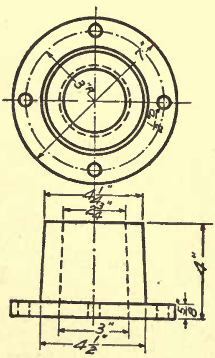


FIG. 191.

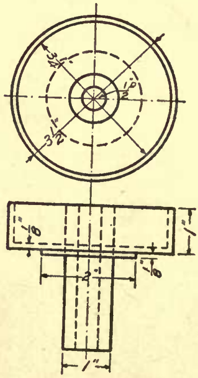


FIG. 192.

27. Draw top view and sectional front view of casting, Fig. 189. Scale 6″ = 1 ft.
28. Draw top view, side view, and sectional front view of body, Fig. 190. Scale 6″ = 1 ft.

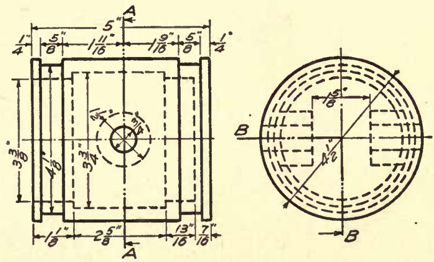


FIG. 193.

Half sections.

29. Draw top view and half-section front view of flanged piece, Fig. 191. Scale 3″ = 1 ft.
30. Draw top view and half-section front view of sleeve Fig. 192. Scale 6″ = 1 ft.

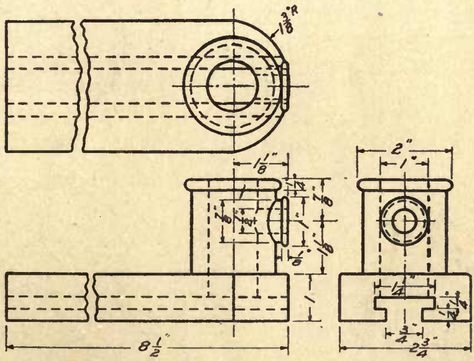


FIG. 194.

31. Draw end view in section, and front view with lower half in section, of piston, Fig. 193. Scale 6″ = 1 ft.
32. Draw top view, front view in half-section, and end view of tool-rest holder, Fig. 194. Scale 6″ = 1 ft.

Group V.—Revolution.

Prob. 33. (1) Draw three views of Fig. 195 in simplest position.

(2) Revolve from position (1) about an axis perpendicular to *H* through 15 degrees.

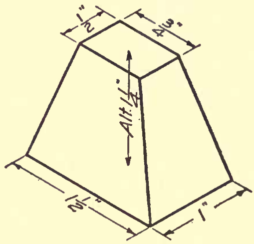


Fig. 195.

(3) Revolve from position (2) about an axis perpendicular to *V* through 45 degrees.

(4) Revolve from position (1) about an axis perpendicular to *P* forward through 30 degrees.

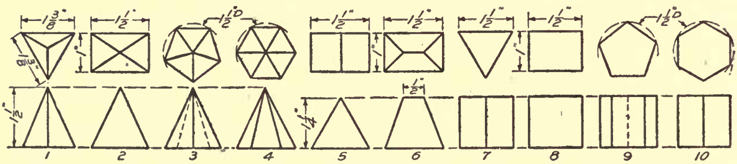


Fig. 195 *A*.

(5) Revolve from position (2) about an axis perpendicular to *P* forward through 30 degrees.

(6) Revolve from position (3) about an axis perpendicular to *P* forward through 30 degrees.

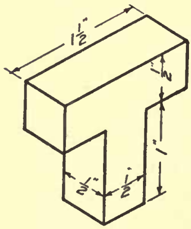


Fig. 196.

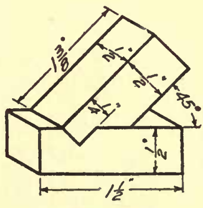


Fig. 197.

(4), (5), (6) may be placed to advantage under (1), (2), and (3) so that the widths of front and top views may be projected down directly.

In problem 33 any of the objects in Fig. 195 *A* may be used instead of Fig. 195.

34. (1) Draw three views of Fig. 196.
(2) Revolve from position (1) about an axis perpendicular to *V* through 30 degrees.
(3) Revolve from position (2) about an axis perpendicular to *H* through 45 degrees.

35. (1) Draw three views of Fig. 197.

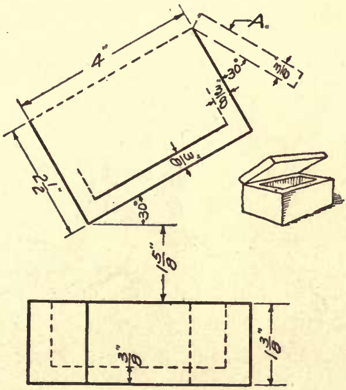


FIG. 198.

(2) Revolve from position (1) about an axis perpendicular to *P* through 30 degrees.

36. Complete top and front views, and draw side view of box in position as shown in Fig. 198, using auxiliary view shown at *A* to obtain projections of lid. Scale 6″ = 1 ft.

Group VI.—True length of lines.

Prob. 37. Find true length of the body diagonal of a 1 1/2″ cube.

38. Find true length of the brace *AB* in tower diagram, Fig. 199.

39. Find true length of any element, as *AB*, of oblique cone, Fig. 200. Scale 6″ = 1 ft.

40. Find true length of line *AB* of pier, Fig. 201. Scale 6″ = 1 ft.

41. Find true length of line *AB* on brace, Fig. 202. Scale 3/4″ = 1 ft.

Group VII.—Drawing from description.

Prob. 42. Draw three views of a pentagonal prism, axis 1″ long and perpendicular to *H*, circumscribing circle of base 1 1/8″ diam., surmounted by a cylindrical abacus (cap) 1 1/2″ diam., 1/2″ thick.

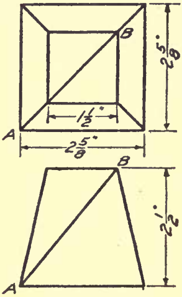


Fig. 199.

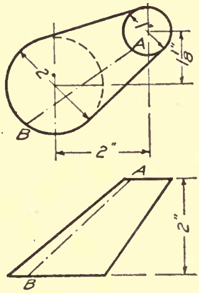


Fig. 200.

43. Draw three views of a triangular card each edge of which is 1 3/4″ long. One edge is perpendicular to *P*, and the card makes an angle of 30 degrees with *H*.

44. Draw three views of a circular card 1 3/4″ diam., in-

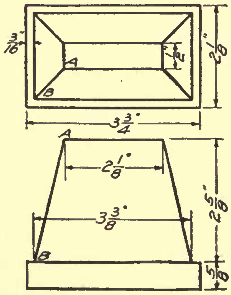


Fig. 201.

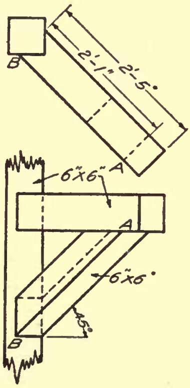


Fig. 202.

clined 30° to *H*, and perpendicular to *V*. (Find 8 points on the curve).

45. Draw three views of a cylinder 1″ diam., 2″ long, with hexagonal hole, 3/4″ long diam., through it. Axis of cylinder parallel to *H* and inclined 30 degrees to *V*.

46. Draw top and front views of a hexagonal plinth whose *faces* are 5/8″ square and two of which are parallel to *H*, pierced by a square prism 2 3/4″ long, base 1/2″ square. The axes coincide, are parallel to *H*, and make an angle of 30 degrees with *V*. The middle point of the axis of the prism is at the center of the plinth.
47. Draw the two projections of a line 2″ long, making an angle of 30 degrees with *V*, and whose *V* projection makes 45 degrees with *G.L.*, the line sloping downward and backward to the left.
48. Draw three views of a square pyramid whose faces are isosceles triangles 1 1/4″ base and 2″ alt., lying with one face horizontal, the *H* projection of its axis at an angle of 30 degrees with *G.L.*
49. Draw three views of a triangular pyramid formed of four equilateral triangles whose sides are 1 3/4″. The base makes an angle of 45 degrees with *H*, and one of the edges of the base is perpendicular to *V*.
50. Draw top and front views of a rectangular prism, base 5/8″ x 1 1/4″ whose body diagonal is 1 3/4″ long. Find projection of prism on an auxiliary plane perpendicular to the body diagonal.

CHAPTER VII.

Developed Surfaces and Intersections.*

A surface may be considered as generated by the motion of a line. Surfaces may thus be divided into two general classes, (1) those which can be generated by a moving straight line, (2) those which can be generated only by a moving curved line. The first are called *ruled surfaces,* the second, *double curved surfaces.* Any position of the moving line is called an *element.*

Ruled surfaces may be divided into (a) *planes,* (b) *single curved surfaces,* (c) *warped surfaces.*

A *plane* may be generated by a straight line moving so as to touch two other intersecting or parallel straight lines.

Single curved surfaces have their elements either parallel or intersecting. These are the cylinder and the cone; and a third surface, which we shall not consider, known as the convolute, in which the consecutive elements intersect two and two.

Warped surfaces have no two consecutive elements either parallel or intersecting. There is a great variety of warped surfaces. The surface of a screw thread and of the pilot of a locomotive are two examples.

Double curved surfaces are generated by a curved line moving according to some law. The commonest forms are *surfaces of revolution,* made by the revolution of a curve about an axis in the same plane, as the sphere, torus, or ring, ellipsoid, paraboloid, hyperboloid, etc.

In some kinds of construction full sized patterns of different faces, or of the entire surface of an object are required; as for example in stone cutting, a templet or pattern giving the shape of an irregular face, or in sheet metal work, a pattern to which a sheet may be cut that when rolled, folded, or formed will make the object.

* The full theoretical discussion of surfaces, their classification, properties, intersections, and development may be found in any good descriptive geometry.

The operation of laying out the complete surface on one plane is called the **development** of the surface.

Surfaces about which a thin sheet of flexible material (as paper or tin) could be wrapped smoothly are said to be developable; these would include figures made up of planes and single curved surfaces only. Warped and double curved surfaces are non-developable, and when patterns are required for their construction they can be made only by some method of approximation, which assisted by the pliability of the material will give the required form. Thus, while a ball cannot be wrapped smoothly, a two-piece pattern developed approximately and cut from leather may be stretched and sewed on in a smooth cover, or a flat disc of metal may be die-stamped, formed, or spun to a hemispherical or other required shape.

We have learned (page 74) the method of finding the true size of a plane surface by projecting it on an auxiliary plane.

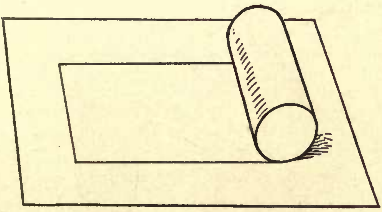


FIG. 203.

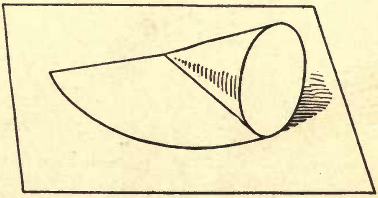


FIG. 204.

If the true size of all the faces of an object made of planes be found and joined in order, at their common edges, the result will be the developed surface. This may be done usually to the best advantage by finding the true lengths of the edges.

The development of a right cylinder would evidently be a rectangle whose width would be the altitude, and length the rectified circumference, Fig. 203; and the development of a right cone with circular base would be a sector with a radius equal to the slant height, and arc equal in length to the circumference of the base, Fig. 204.

In the laying out of real sheet metal problems an allowance must be made for seams and lap, and in heavy sheets for the thickness and for crowding of the metal; there is also the consideration of the commercial sizes of material, and of economy in cutting, in all of which some practical shop knowledge is necessary. In this chapter we will be confined to the principles alone.

In the development of any object we must first have its projections, drawing only such views or parts of views as are necessary to give the lengths of elements and true size of cut surfaces.

To develop the hexagonal prism, Fig. 205.

Since the base is perpendicular to the axis it will roll out into the straight line *AB*. This line is called by sheet metal workers the "stretchout." Lay off on *AB* the length of the perimeter of the base, and at the points 1, 2, 3, etc., erect perpendiculars,

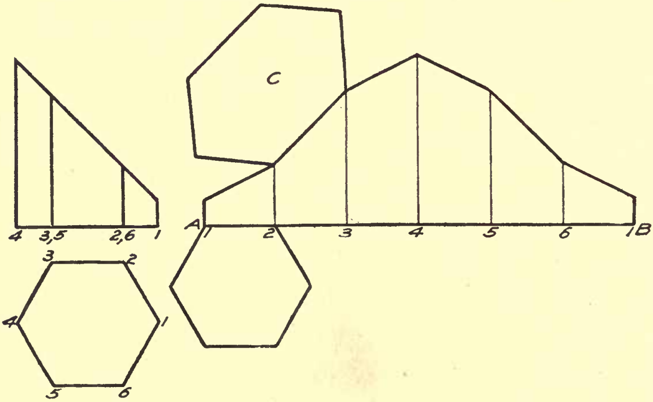


FIG. 205.—Development of hexagonal prism.

called "measuring lines," representing the edges. Measure on each of these its length as given on the front view, and connect the points. Attach to one of the top lines the true size of the cut face *C*, and to one of the bottom lines the size of the base. The figure will then be the development of the entire surface of the prism. It is customary to make the seam on the shortest edge.

To develop the cylinder, Fig. 206.

In rolling the cylinder out on a tangent plane the base, being perpendicular to the axis, will develop into a straight line. Divide the base, here shown as a bottom view, into a number of equal parts, representing elements. Project these elements up to the front view. Draw the stretchout and measuring lines as before. Transfer the lengths of the elements in order, either by projection or with dividers, and connect the points by a smooth curve. This might be one-half of a two-piece elbow. Three-piece, four-piece, or five-piece elbows may be drawn similarly, as

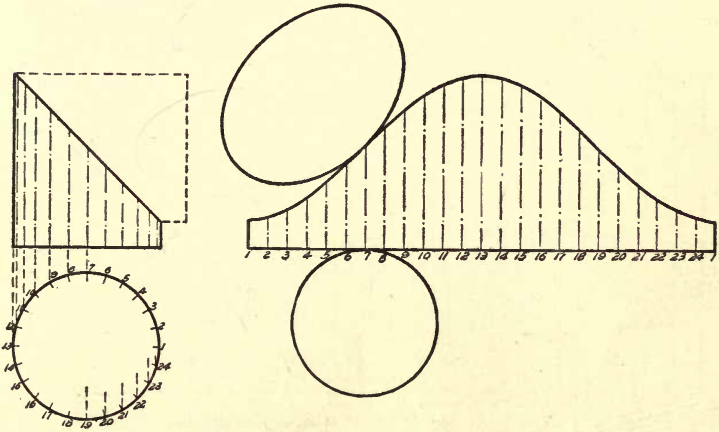


FIG. 206.—Development of cylinder.

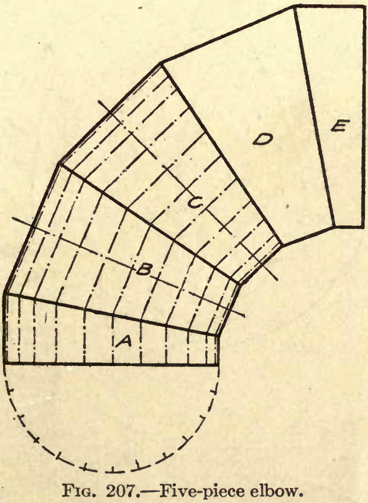


FIG. 207.—Five-piece elbow.

illustrated in Fig. 207. As the base is symmetrical, one-half only need be drawn. In these cases the sections as *B* will develop on their center lines as stretchouts, and measurements will

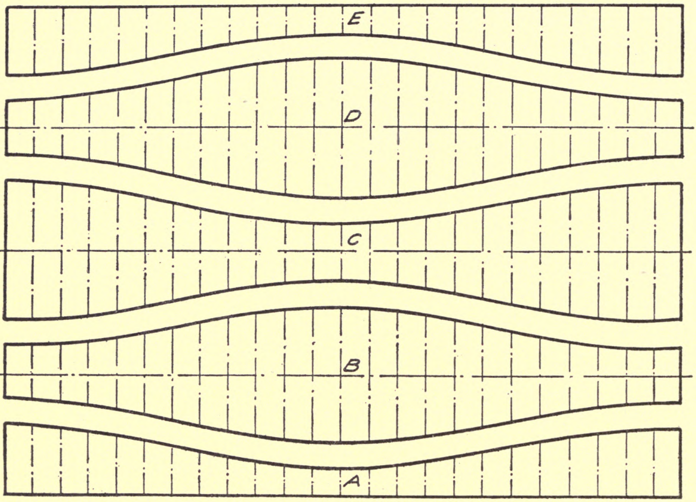


FIG. 208.—Development of five-piece elbow.

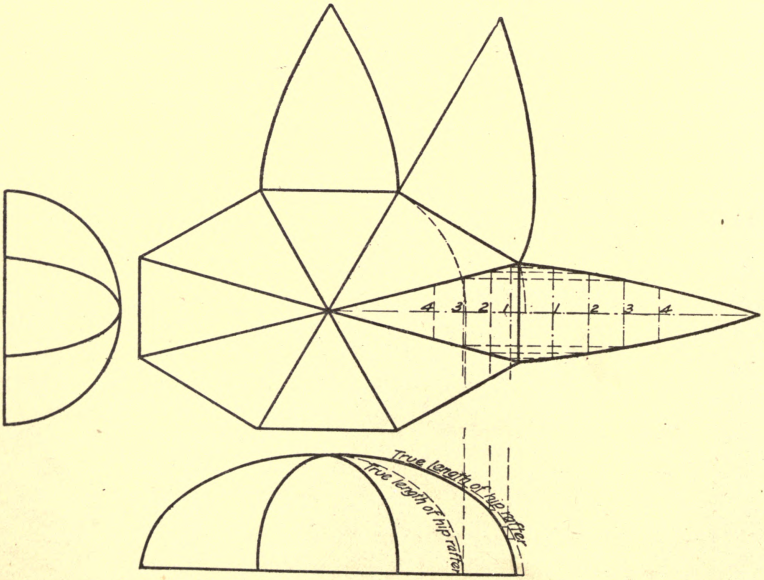


FIG. 209.—Development of octagonal dome.

be taken on each side of the center line, since the center line represents a "right section," *i.e.* the section cut by a plane perpendicular to the axis.

Evidently any elbow could be cut from a single sheet without waste if the seams were made alternately on the long and short sides. Fig. 208.

The development of the octagonal dome Fig. 209 illustrates an application of the development of cylinders.

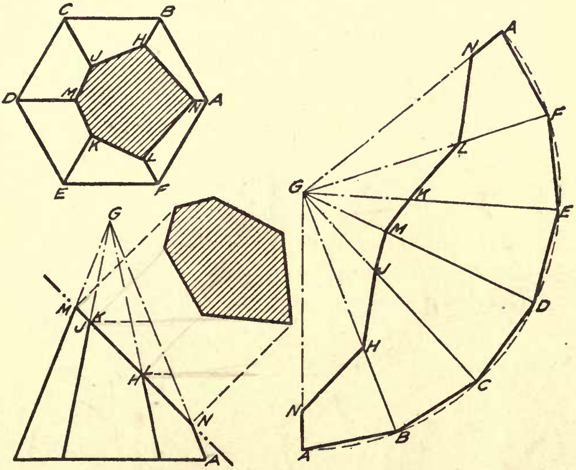


FIG. 210.—Development of hexagonal pyramid.

To develop the hexagonal pyramid, Fig. 210.

The edge *GA* is shown on the front view in its true length. As the edges are all of equal length, an arc may be drawn with the radius *GA* and the perimeter of the base stepped off on it. The cutting plane intersects the edges at the points *HJKL*. Revolve these points to *GA* to find the true length of the intercepts and measure these distances on the corresponding lines of the development. Find the true size of the cut face and attach it to the development.

The rectangular pyramid Fig. 211 is develped in a similar way, but as the edge *EA* is not parallel to the plane of projection it must be revolved to *EA′* to obtain its true length.

To develop the truncated cone, Fig. 212.

Divide the base into a convenient number of equal parts, project these points on the front view and draw the elements through them. With a radius equal to the slant height of the cone, *i.e.* the true length of the element *OA*, draw an arc and lay off on it the circumference of the base; draw the developed posi-

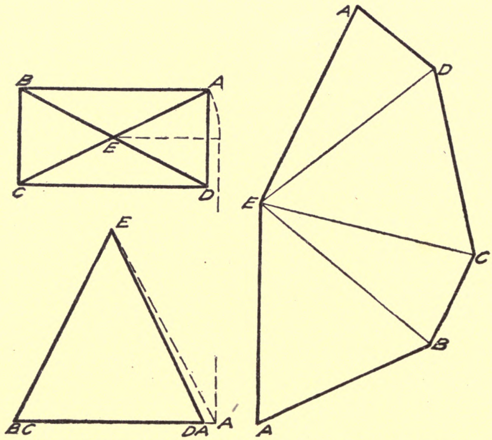


FIG. 211.—Development of rectangular pyramid.

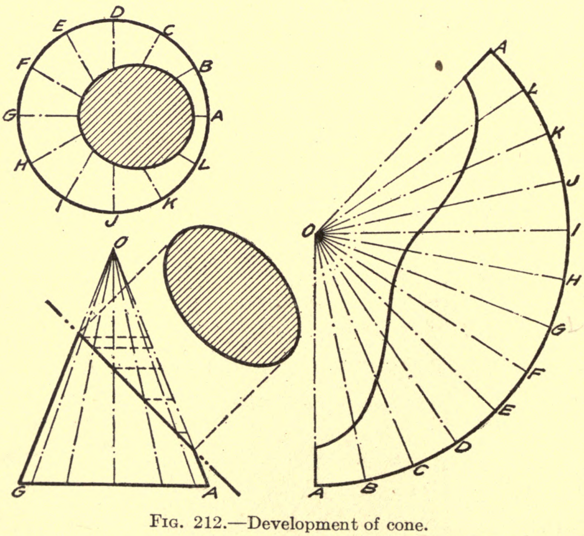


FIG. 212.—Development of cone.

tions of the elements and on them measure the true lengths from the vertex to the cutting plane, found by revolving each point over to the extreme element *OA*.

Double-curved surfaces are developed approximately by assuming them to be made up of parts of developable surfaces. Thus the sphere may be made of sections of cylinders whose

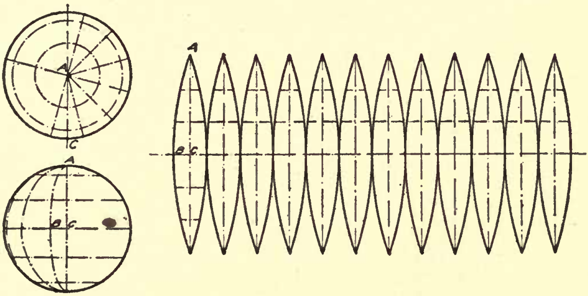


FIG. 213.—Sphere, gore method

diameter is equal to the diameter of the sphere, and developed as in Fig. 213, or it may be made up of frustra of cones and developed as in Fig. 214.

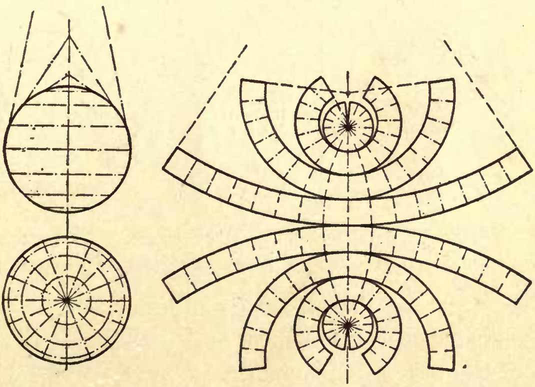


FIG. 214.—Sphere, zone method.

Triangulation.

The commonest and best method for approximate development is by triangulation, *i.e.*, assuming the surface to be made up of a large number of triangular strips, or plane triangles with very short bases. This is used for all warped surfaces, and for oblique cones, which, although single-curved surfaces, and capable of true theoretical development, can be done much more easily and accurately by triangulation.

The method is extremely simple. It consists merely in dividing the surface into triangles, finding the true lengths of the sides of each, and constructing the triangles one at a time, joining them on their common sides. A study of Fig. 215, **the development of an oblique cone,** will explain the method completely.

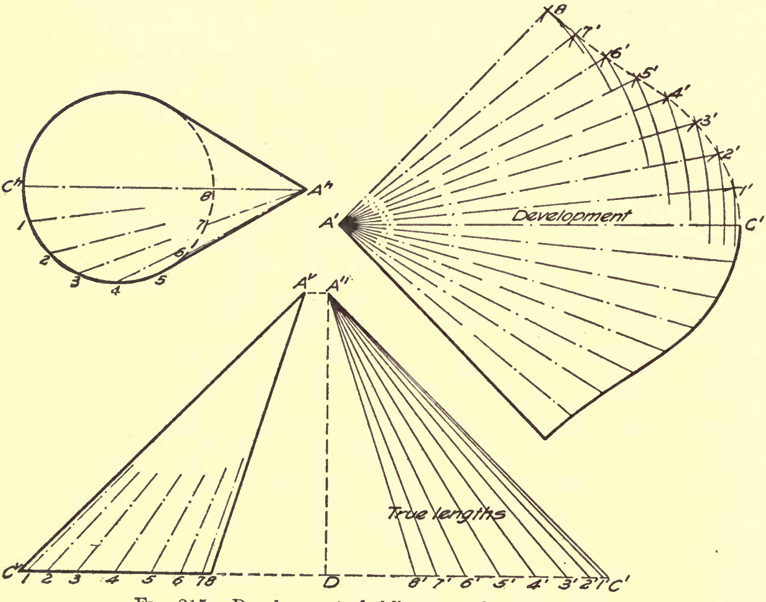


FIG. 215.—Development of oblique cone by triangulation.

In this case the triangles all have a common vertex, the apex of the cone, their sides are elements, and their bases the chords of short arcs of the base of the cone.

Divide the base into a number of equal parts 1, 2, 3, etc. (as the plan is symmetrical about the axis A^hC^h one-half only need be constructed). If the seam is to be on the short side, the line AC will be the center line of the development and may be drawn directly at $A'C'$ as its true length is given. Find the true lengths of the elements $1A$, $2A$, etc., by revolving them until parallel to V. This may be done without confusing the H and V projections, by constructing the triangles for the true lengths in an auxiliary figure as shown, laying off the lengths of the H projections as bases on the line DC'' and connecting with the point A''. With A' as center and radius $A'1'$ draw an arc on each side of $A'C'$. With C' as center and radius C^h1 intersect these arcs at $1'$. Then $A'1'$ will be the developed position of the element $A1$. With $1'$ as center and arc 1, 2, intersect $A'2'$ and continue the operation.

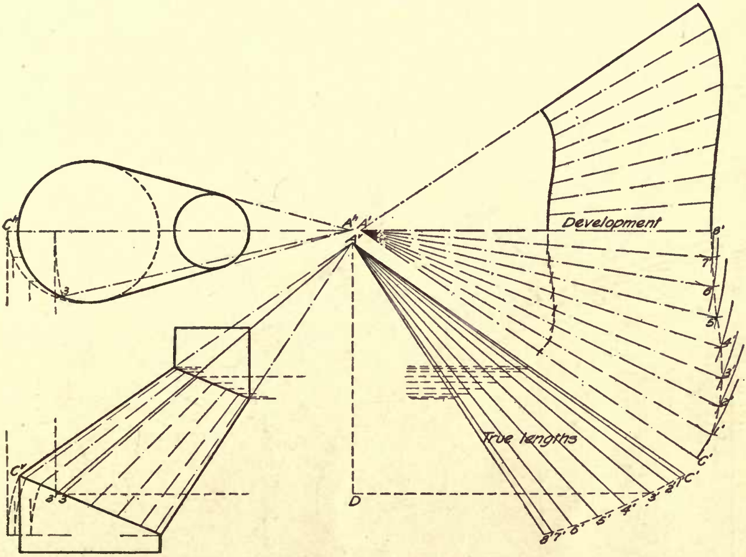


FIG. 216.—Development of oblique cone by triangulation.

Fig. 216 is an oblique cone connecting two parallel pipes of different diameters. This is developed in the same way as Fig. 215, except that the true size of the base is not given in the top view and must be revolved until parallel to H, as shown.

Transition Pieces.

Transition pieces are used to connect pipes or openings of different shapes of cross-section. Fig. 217, for connecting a round pipe and a square pipe on the same axis, is typical. These are always developed by triangulation.

The piece shown in Fig. 217 is evidently made up of four isosceles triangles whose bases are the sides of the square, and four parts of oblique cones. As the top view is symmetrical about both center lines, one-fourth only need be divided. The construction is illustrated clearly in the figure.

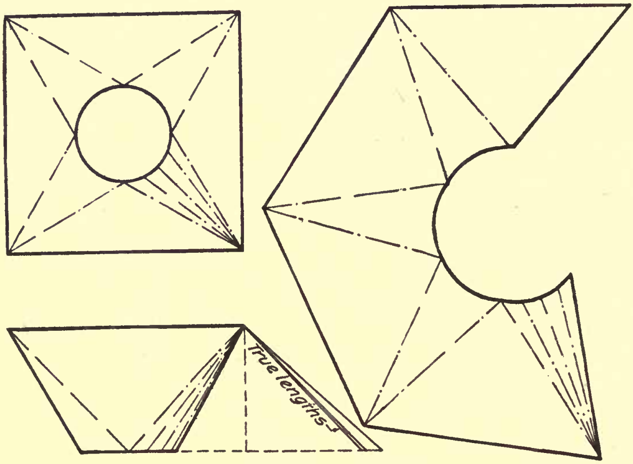


FIG. 217.—Transition piece.

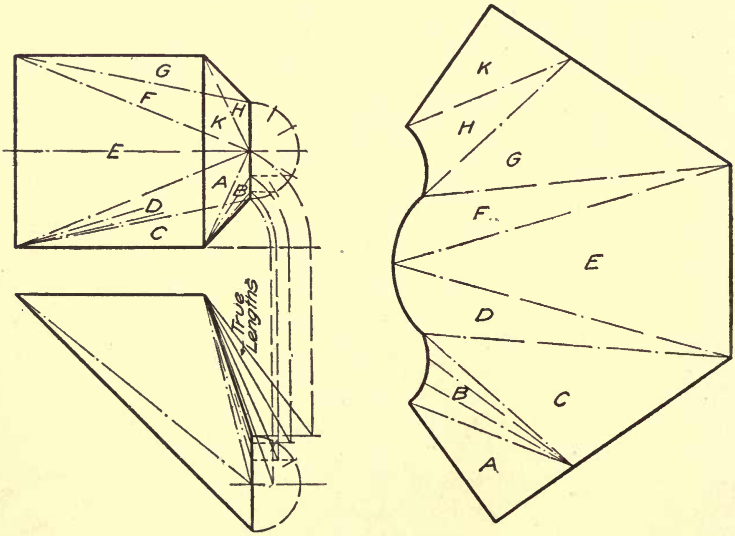


FIG. 218.—Transition piece.

Fig. 218 is another transition piece from rectangular to round. By using the turned sections of one-half the round opening, the need of the full side view is avoided.

The Intersection of Surfaces.*

The habit should be formed of thinking of surfaces as made up of elements, the successive positions of the generating line. When two surfaces intersect, their common line, the line of intersection, would be found by connecting the points at which the elements of one surface pierce the other.

Two reasons make it necessary for the draftsman to be familiar with the methods of finding the intersections of surfaces, first, intersections are constantly occurring on working drawings, and must be represented, second, in sheet metal combinations the intersections must be found before the pieces can be developed. In the first case it is only necessary to find a few points usually, and "guess in" the curve; in the second case enough points must be determined to enable the development to be laid out accurately.

Intersection of Two Cylinders.

Any practical problem resolves itself into some combination of the geometrical type forms of solids.

In Fig. 219 the intersection of two cylinders might represent a dome on a boiler. If the top view of the cylinder *A* is divided

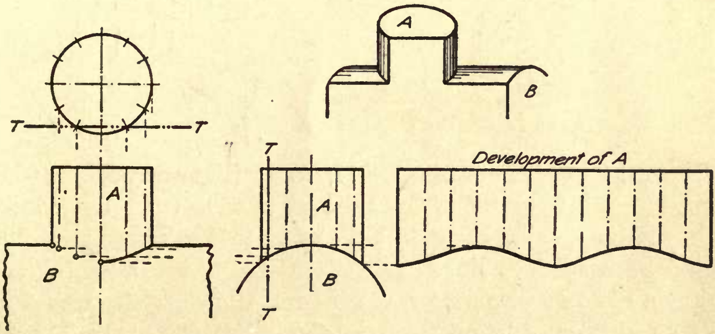


FIG. 219.—Intersection of two cylinders.

into a number of equal parts the points will represent the top views of elements. Draw the side views of these elements, which will pierce the cylinder *B* as shown. If these points be projected across to meet the corresponding elements on the front view the intersections will be points on the curve. Since the axes inter-

* Often called "penetrations" or "interpenetrations."

sect, the projection of the invisible part of the curve will coincide with the visible part.

The method of development of the cylinder *A* is evident from the figure.

In general, the method of finding the line of intersection of any two surfaces is to pass a series of planes through them in such a way as to cut from each the simplest lines. The intersection of these lines will be points on the curve.

In Fig. 219 the plane *T* may be assumed as cutting out two elements from the cylinder *A* whose intersections with the element cut from the cylinder *B*, being points common to both cylinders, will be points on the curve, as shown in the sketch.

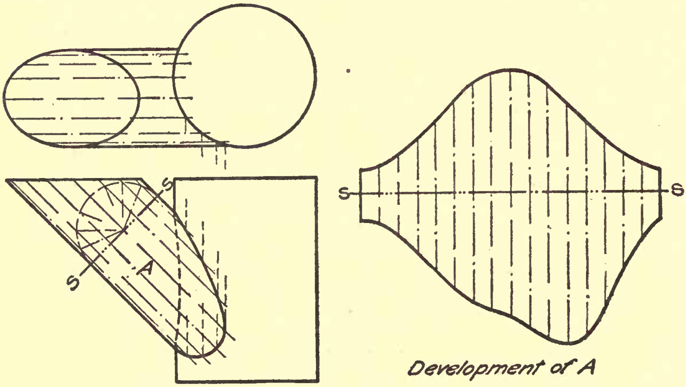


FIG. 220.—Two cylinders, axes not intersecting.

This principle is illustrated in Fig. 220 with two cylinders whose axes do not intersect. If the cylinder *A* were to be developed a right section as at *S-S* would have to be taken, whose stretchout would be a straight line. If the cutting planes were taken at uniform distances apart, or at random, the elements would not be spaced uniformly on the stretchout but would be found as they project on the turned section of *S-S*.

Intersection of Cylinder and Cone.

To find the intersection of a cylinder and a cone the cutting planes may be taken so as to pass through the vertex of the cone and parallel to the elements of the cylinder, thus cutting elements from both cylinder and cone; or with a right cone they may be taken perpendicular to the axes, so as to cut circles from the cone. Both these methods are illustrated in Fig. 221. Some judgment is necessary in the selection both of the direction and number of the cutting planes. More points need be found at the

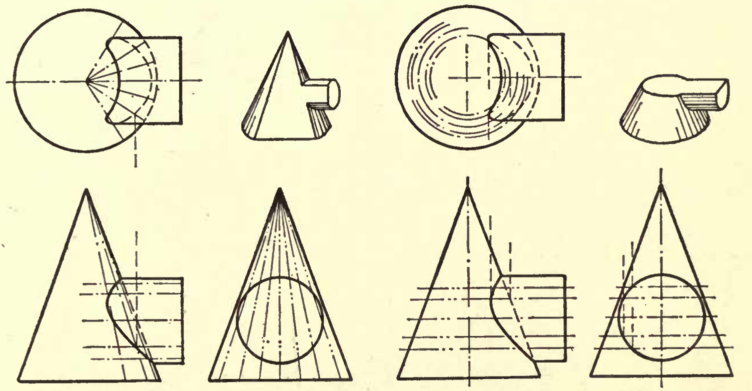


FIG. 221.—Intersection of cylinder and cone.

places of sudden curvature or change of direction of the line of intersection.

Cutting spheres instead of planes may be used to advantage in some cases. If any surface of revolution be cut by a sphere whose

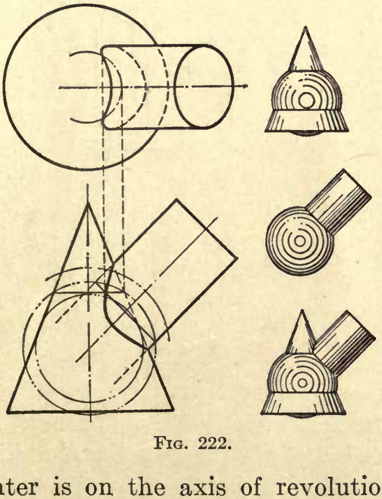


FIG. 222.

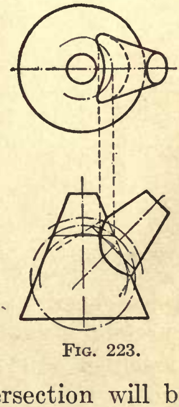


FIG. 223.

center is on the axis of revolution, the intersection will be a circle. This principle may be employed in finding the intersection of a cylinder and cone of revolution, whose axes intersect, as in Fig. 222. If spheres be drawn with center at the intersection of the axes they will cut circles from each, whose intersection will be points on the curve.

The intersection of two cones of revolution may be found in the same way, Fig. 223. The cone *B* would be developed by cutting a right section as *S-S* whose stretchout will be a circle arc, locating the elements on it and finding the true length of each from the vertex to the line of intersection

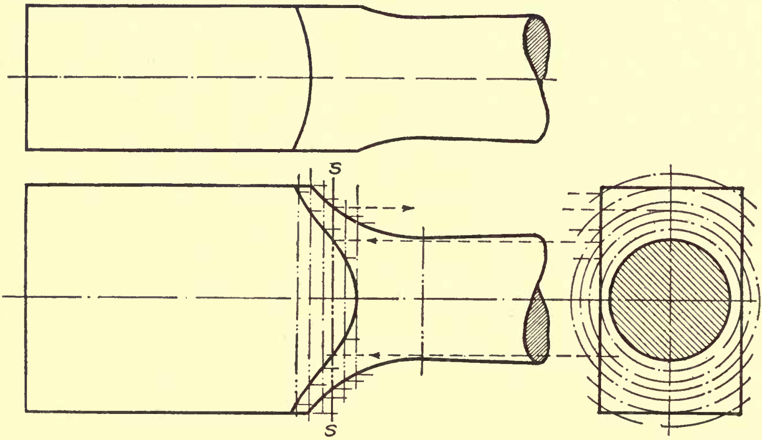


Fig. 224.—Intersection of a surface of revolution and a plane.

It is often necessary on a drawing to represent the line of intersection of a plane and a surface of revolution, such as is shown in Fig. 224. The method is clearly illustrated in the figure. A series of planes as *S-S* are passed perpendicular to the axis of revolution, cutting out the circles shown on the end view. The points at which these circles cut the "flat" are projected back as points on the curve.

PROBLEMS.

Selections from the following problems may be constructed accurately in pencil, without inking. Any practical problem can be resolved into some combination of the "type solids," and the exercises given illustrate the principles involved in the various combinations.

When time permits, an added interest in developments may be found by working the problems on suitable paper, allowing for lap, and cutting them out.

In the sheet metal shops, development problems, unless very complicated, are usually laid out directly on the iron.

Except when noted, the following problems may be drawn in a space 4″ x 5″.

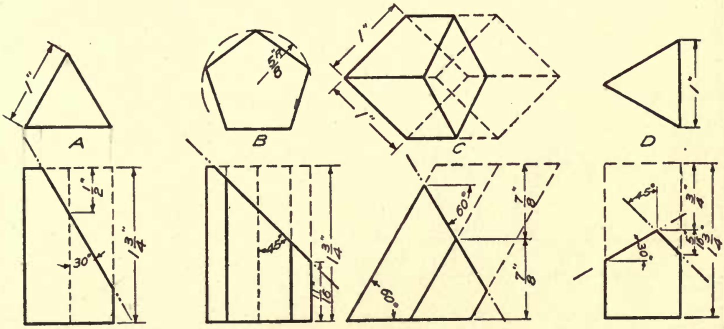


FIG. 225.

Group I.—Prisms, Fig. 225.

Prob. 1. Develop entire surface of triangular prism (A)

2. Develop entire surface of pentagonal prism (B)

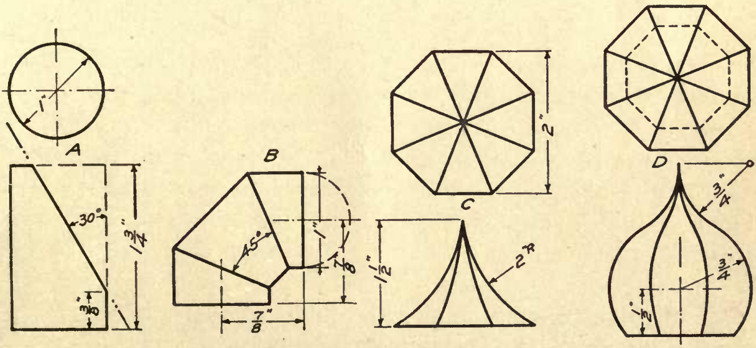


FIG. 226.

3. Develop entire surface of oblique square prism (C)

4. Develop entire surface of triangular prism (D)

Group II.—Cylinders, Fig. 226.

Prob. 5. Develop entire surface of cylinder (A)

6. Develop three-piece elbow (B)

7. Develop one section of octagonal

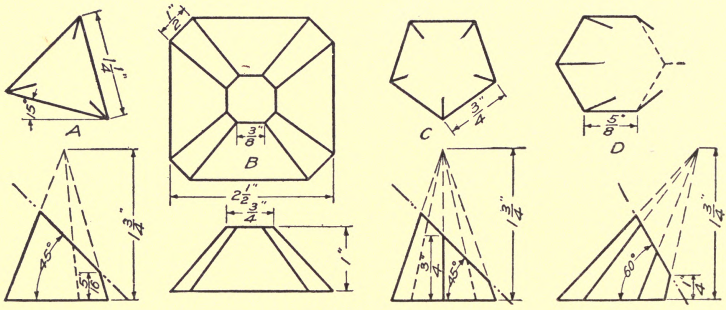


Fig. 227.

roof and find true shape of a hip rafter (C)

8. Develop one section of dome, and find true shape of hip (D)

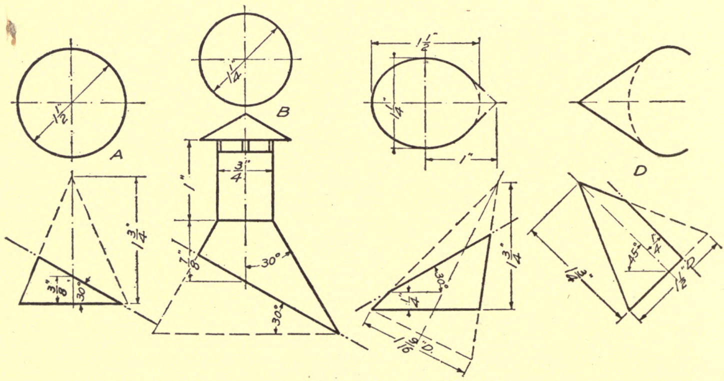


Fig. 228.

Group III.—Pyramids, Fig. 227.

Prob. 9. Develop entire surface of triangular pyramid (A)

10. Develop pattern for octagonal lamp shade (B)

11. Complete top view, and develop surface of pentagonal pyramid (C)

12. Complete top view and develop surface of oblique hexagonal pyramid (D)

Group IV.—Cones, Fig. 228.

Prob. 13. Complete top view, and develop cone (A)

14. Complete top view, and develop flange and hood cones of (B)

15. Complete top view, and develop cone (C)

16. Complete top view, and develop cone (D)

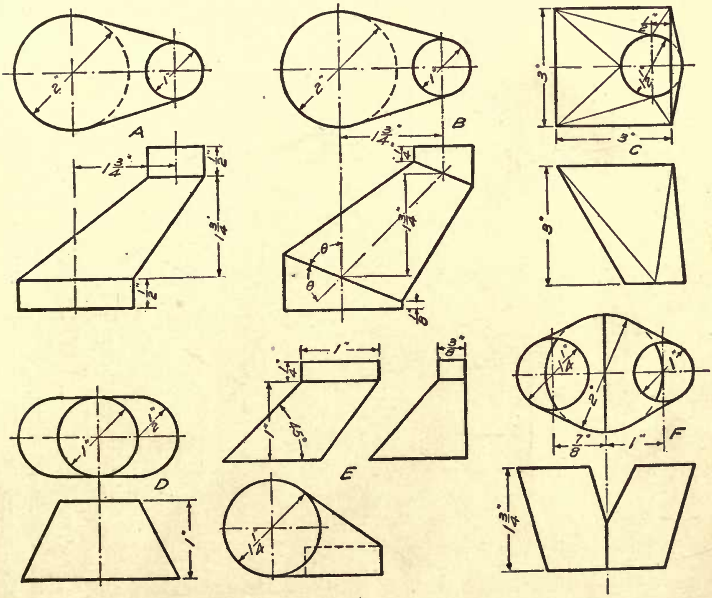


Fig. 229.

Group V.—Triangulation, Fig. 229 (space 5″ x 8″).

Prob. 17. Develop conical connector (A)

18. Develop connnector (B)

19. Develop transition piece (C)

20. Develop transition piece (D)

21. Develop offset boot (E)

22. Develop three-way pipe (F)

Group VI.—Intersection of Prisms, Fig. 230 (space 5″ x 8″)

Prob. 23. Find the line of intersection of two prisms (A)

24. Find the line of intersection of two prisms (B)

25. Find the line of intersection of two prisms (C)

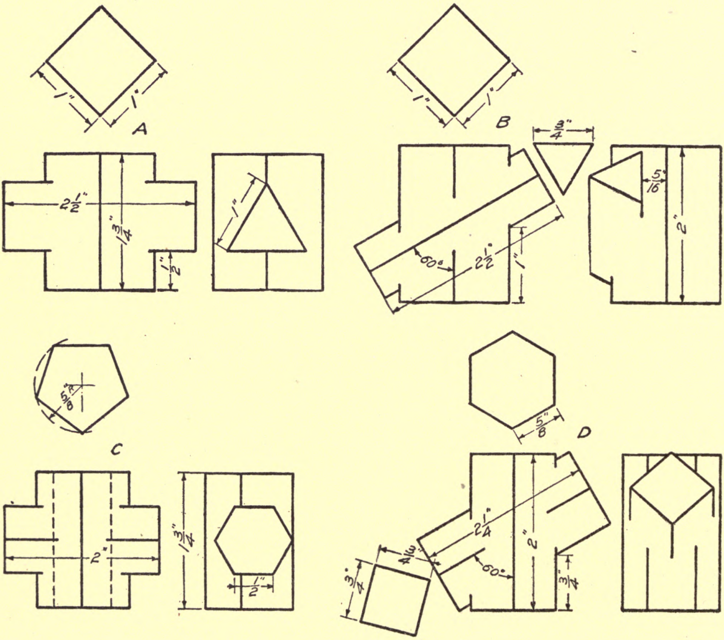


Fig. 230.

26. Find the line of intersection of two prisms (D)

Develop the surface of the larger prism in Probs. 23, 24, 25, 26.

Group. VII.—Intersection of Cylinders, Fig. 231.

Prob. 27. Find the line of intersection of two cylinders (A)

28. Find the line of intersection of two cylinders (B)

29. Find the line of intersection of two cylinders (C)
30. Find the line of intersection of two cylinders (D)

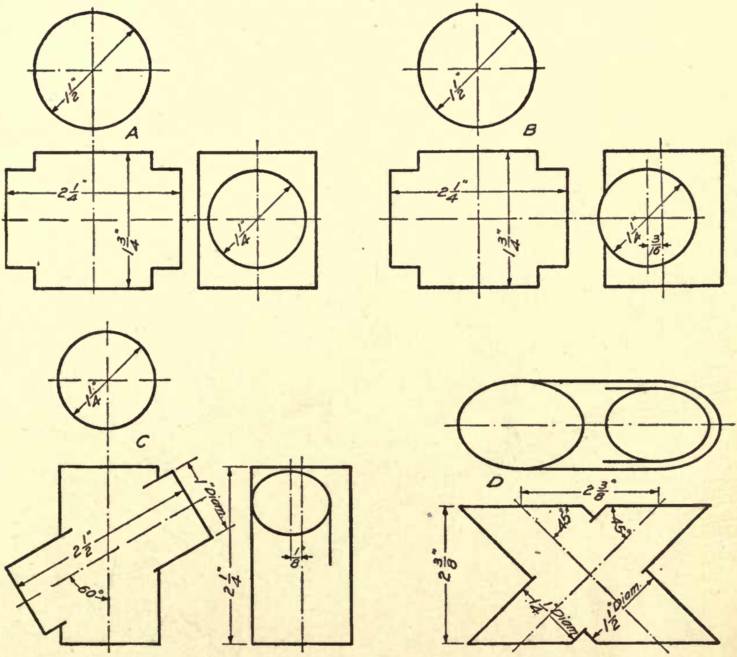


Fig. 231.

Group VIII.—Intersection of Cylinder and Cone, Fig. 232.

Prob. 31. Find the line of intersection of cylinder and cone (A)
32. Find the line of intersection of cylinder and cone (B)
33. Find the line of intersection of cylinder and cone (C)
34. Find the line of intersection of cylinder and cone (D)
35. Find the line of intersection of cylinder and cone (E)
36. Find the line of intersection of cylinders and cone (F)

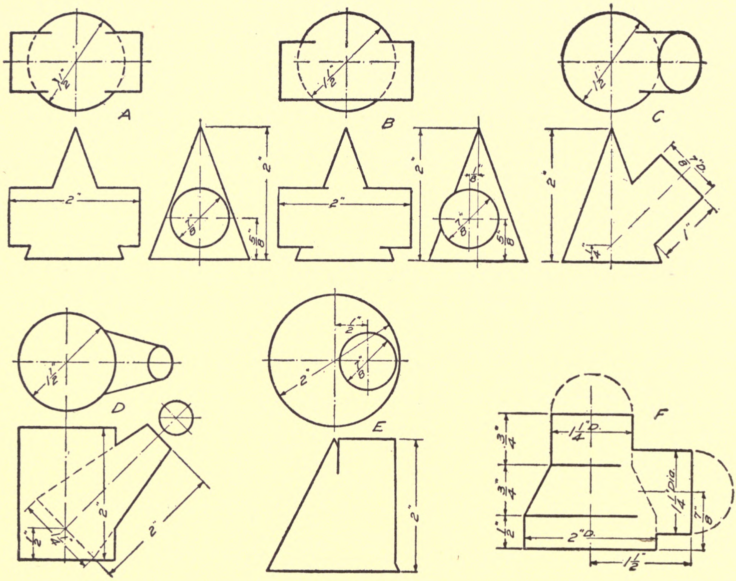


FIG 232.

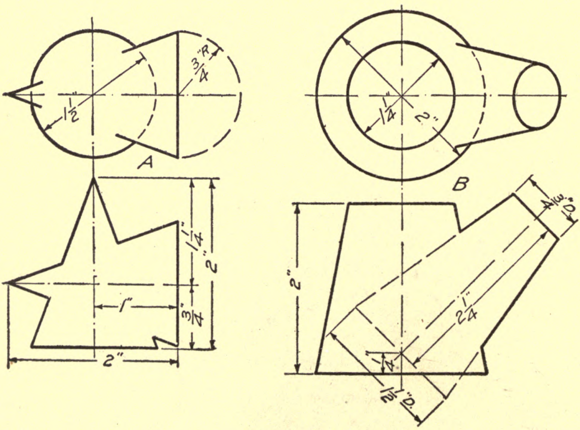


FIG. 233.

Group IX.—Intersection of Two Cones, Fig. 233.

Prob. 37. Find line of intersection of two cones (A)

38. Find line of intersection of two cones (B)

If desired, any of the figures in Groups VII, VIII and IX may be developed, in a space 4″ x 5″.

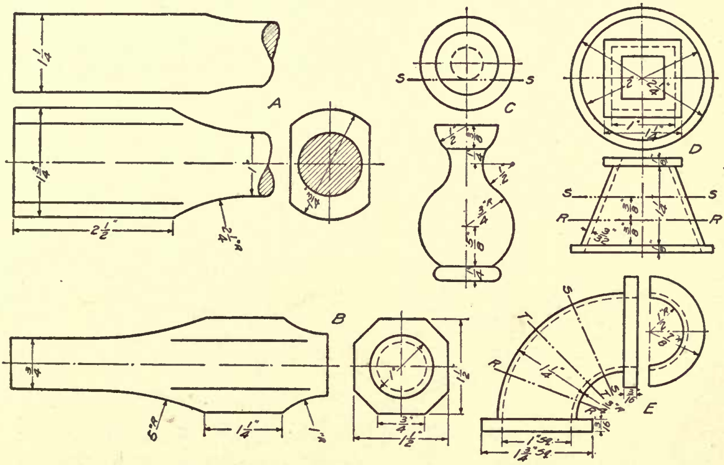


Fig. 234.

Group X.—Intersection of Surfaces by Planes, Fig. 234.

Prob. 39. Find line of intersection of (A)

40. Find line of intersection of (B)

41. Find line of intersection of (C)

42. Find line of intersection cut by planes *R* and *S* from cast-iron transition piece (D)

43. Find line of intersection cut by planes *R S* and *T* from cast-iron transition elbow (E)

CHAPTER VIII.

Pictorial Representation.

We have noted the difference between perspective drawing and orthographic projection. Perspective drawing shows the object as it appears to the eye, but its lines cannot be measured directly. Orthographic projection shows it as it really is in form and dimensions, but to represent the object completely we have found that at least two projections were necessary, and that an effort of the geometrical imagination was required to visualize it from these views. To combine the pictorial effect of perspective drawing with the possibility of measuring the principal lines directly, several kinds of one plane projection or conventional picture methods have been devised, in which the third dimension is taken care of by turning the object in such a way that three of its faces are visible. With the combined advantages will be found some serious disadvantages which limit their usefulness. They are distorted until the appearance is often unreal and unpleasant; only certain lines can be measured; the execution requires more time, particularly if curved lines occur, and it is difficult to add many figured dimensions, but with all this, the knowledge of these methods is extremely desirable and they can often be used to great advantage. Structural details not clear in orthographic projection may be drawn pictorially, or illustrated by supplementary pictorial views. Technical illustrations, patent office drawings and the like are made advantageously in one plane projection; layouts and piping plans may be shown, and many other applications will occur to draftsmen who can use these methods with facility. One of the uses to which we shall apply them is in testing the ability to read orthographic projections bv translating into pictorial representation.

Isometric Drawing.

The simplest of these systems is isometric drawing.

If a cube in orthographic projection, Fig. 235, be conceived as revolved about a vertical axis through 45 degrees, then tilted forward until the edge AD is foreshortened equally with AB and AC, the front view in this position is said to be in isometric (equal measure) projection. The three lines AB, AC and AD make equal angles with each other and are called the isometric axes. Since parallel lines have their projections parallel, the other edges of the cube will be respectively parallel to these axes. Any line parallel to an isometric axis is an isometric line, and the planes of these axes and all planes parallel to them are called isometric planes. It will thus be noticed that any line or plane

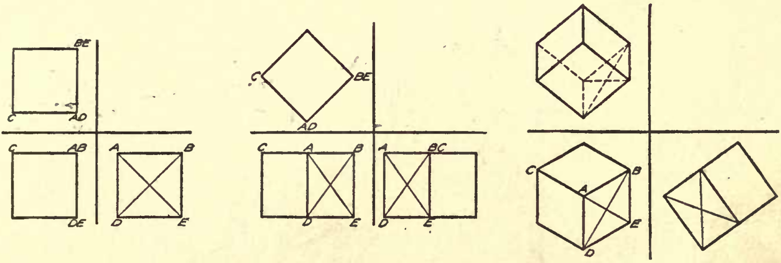


Fig. 235.—Revolution to isometric position.

which in its orthographic projection is perpendicular to either of the reference planes, will be an isometric line or plane.

In this isometric projection the lines have been foreshortened to approximately 81/100 of their length and an isometric scale to this proportion *might* be made as drawn in Fig. 236. If the amount of foreshortening be disregarded and the full lengths laid off on the axes, a figure slightly larger but of exactly the same shape would result. This is known as **isometric drawing.** As the effect of increased size is usually of no consequence, and the advantage of measuring the lines directly with an ordinary scale is a great convenience, isometric drawing is used almost exclusively instead of isometric projection.

To make an isometric drawing of a rectangular object start with the three axes 120 degrees apart, drawing one vertical, the other two with the 30-degree triangle. Let this represent the front corner of the object and measure on the three lines its length, breadth and thickness, Fig. 237. To draw intelligently in isometric it is only necessary to remember the direction of the three principal isometric planes. Hidden lines are always omitted except when necessary for the description of the piece.

Lines not parallel to one of the isometric axes are called non-isometric lines. The first rule is, *measurements can be made only on isometric lines;* and conversely, measurements cannot be made on non-isometric lines. Thus the diagonals of the face of the cube, Fig. 235, are non-isometric lines, and although equal in

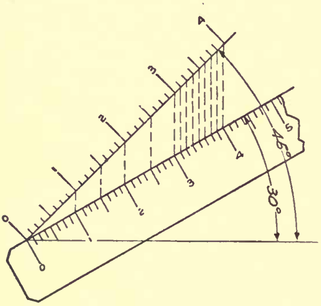


FIG. 236.—An isometric scale.

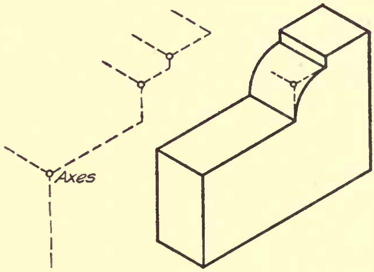


FIG. 237.—The isometric axes.

length, are evidently of very unequal length on the isometric drawing.

To draw an object composed of non-isometric lines, an isometric construction must be built up and the points located by

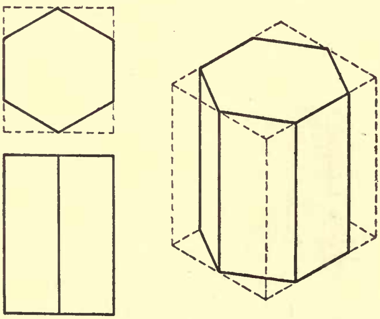


FIG. 238.—Isometric construction lines.

isometric coordinates. Thus the hexagonal prism, Fig. 238, may be enclosed in the rectangular box and the corners located on these isometric lines by measuring the orthographic projection.

It is not at all necessary actually to enclose the object in rectangular construction. In many instances it is better to get the isometric coordinates by offsets. Figs. 239 and 240 are self-explanatory.

Of course angles in isometric drawing cannot be measured in degrees. In general to represent any angles, or combination of non-isometric lines, their orthographic view must be drawn first,

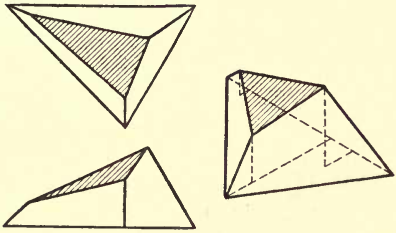


FIG. 239.—Offset construction.

adding construction lines which can be drawn isometrically, and transferring the measurements from the orthographic to these isometric lines.

A circle on any isometric plane would be projected as an ellipse. It may be constructed from the orthographic projection by coordinates, or by the method of conjugate diameters. A

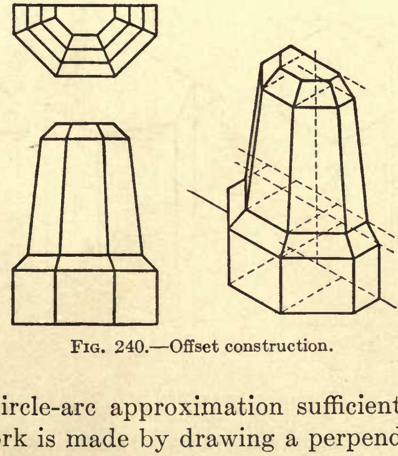


FIG. 240.—Offset construction.

four-centered circle-arc approximation sufficiently accurate for all ordinary work is made by drawing a perpendicular from the point of tangency, that is, the middle point of each side of the square. As the center of any arc tangent to the line at this point must lie on the perpendicular, the intersections of these perpendiculars would be centers for arcs tangent to two sides, Fig. 241. Two of these intersections will evidently fall in the corners of the square, as the lines are altitudes of equilateral triangles. The construction of Fig. 241 may thus be made by simply drawing

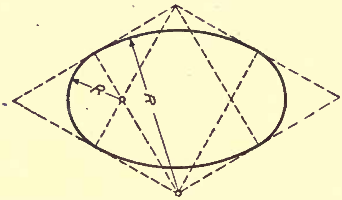


FIG. 241.—Approximate isometric circle.

60-degree lines from the corners *A* and *B*. To draw any circle-arc, the isometric square of its diameter should be drawn in the plane of the face, with as much of this construction as is necessary to find centers for the part of the circle needed. Fig. 242 shows arcs on the three visible faces with the construction indicated.

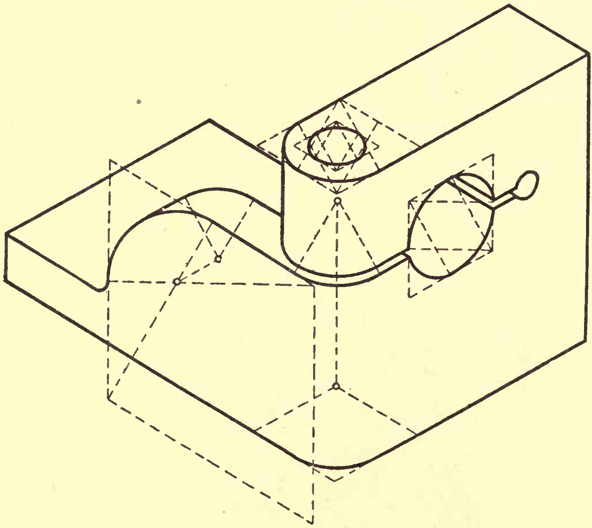


FIG. 242.—Construction of isometric circles.

If a true ellipse be plotted in the same square as this four-centered approximation it will be a little longer and narrower, and of more pleasing shape, but in the great majority of drawings the difference is not sufficient to warrant the extra expenditure of time required in execution. The construction of a closer approximation with eight centers as illustrated in Fig. 243. This might be used when a more accurate drawing of an inscribed circle is required.

It is evident that the isometric drawing of a sphere would

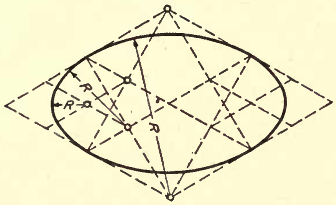


Fig. 243.

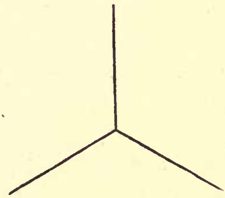


Fig. 244.—Reversed axes.

have a diameter equal to the long axis of the ellipse inscribed in the isometric square of the real diameter of the sphere, as this ellipse would be the isometric of a great circle of the sphere.

It is often desirable to show the lower face of an object by tilting it back instead of forward, thus reversing the axes to the

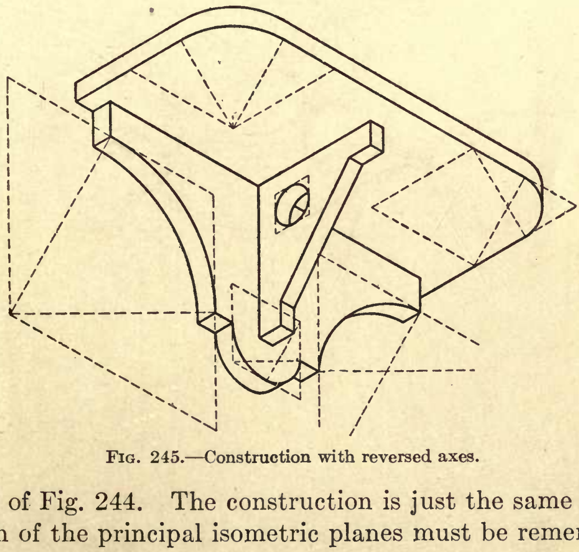


Fig. 245.—Construction with reversed axes.

position of Fig. 244. The construction is just the same but the direction of the principal isometric planes must be remembered. Figs. 245 and 246 are applications. Sometimes a piece may be shown to better advantage with the main axis horizontal as in Fig. 247.

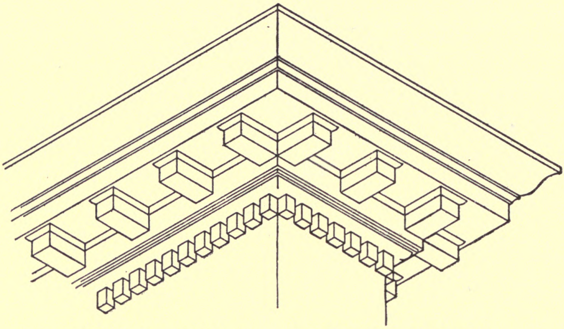


FIG. 246.—Architectural detail on reversed axes.

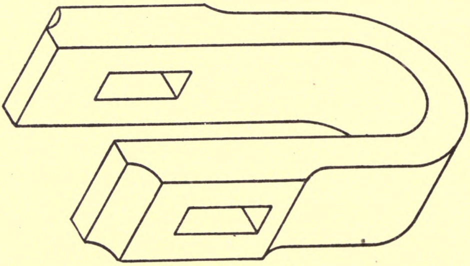


FIG. 247.—Main axis horizontal.

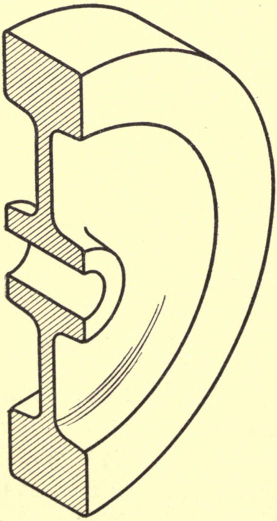


FIG. 248.—Isometric section.

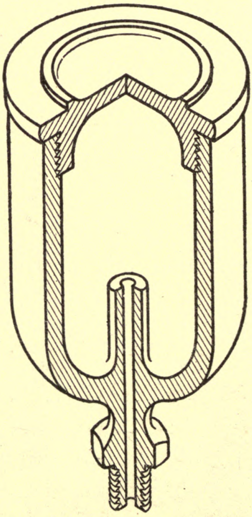


FIG. 249.—Isometric half section.

The isometric section and half section may sometimes be employed to good advantage. The cutting planes are taken as isometric planes, and the section lining done in a direction to give the best effect. Figs. 248 and 249 are examples.

Shade lines in isometric drawings have no value so far as aiding in the reading is concerned, but they may by their contrast add

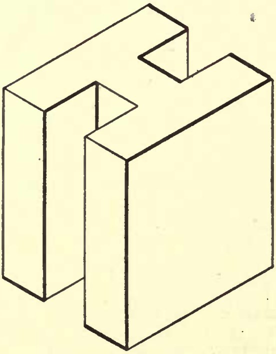


Fig. 250.

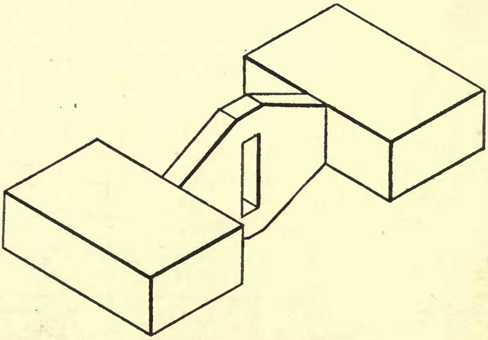


Fig. 251.

some attractiveness to the appearance. Assuming the light as coming from the left in the direction of body diagonal of a cube, and disregarding shadows, shade lines separating light from dark faces would be added as in Fig. 250.

Another method popular among patent draftsmen and others using this kind of drawing for illustration, is to bring out the nearest corner with heavy lines, as Fig. 251.

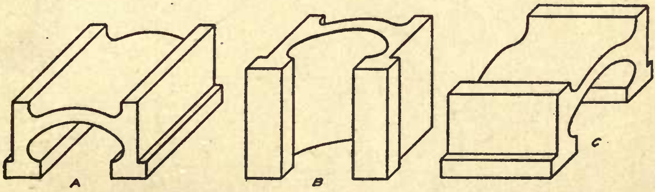


Fig. 252.—Illustration of first rule.

Oblique projection, sometimes called cavalier projection, is based on the theoretical principle that with one face of the object parallel to the picture plane, if the projectors instead of being perpendicular to it as in orthographic and isometric, make an angle of 45 degrees with it in any direction, lines perpendicular to the plane would be projected in their true length. It would thus be similar to isometric in having three axes, representing three mutually perpendicular lines, upon which measurements could be made. Two of the axes would always be at right angles to each other, being in the plane parallel to the picture plane,

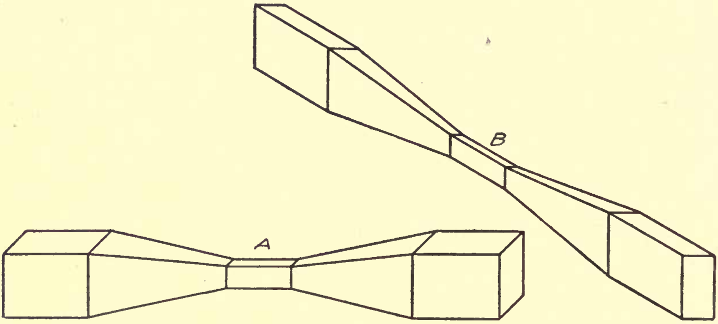


FIG. 253.—Illustration of second rule.

and the cross axis might be at any angle, 30 degrees being generally used. Thus any face parallel to the picture plane will be projected without distortion, an advantage over isometric of particular value in the representation of objects with circular or

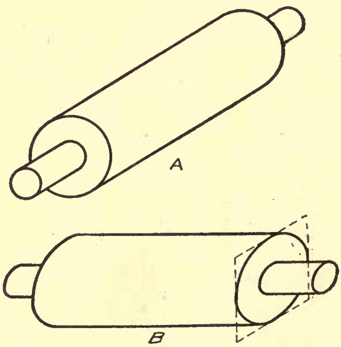


FIG. 254.—(*A*) not (*B*).

irregular outline, and the first rule for oblique projection would be, **place the object with the irregular outline or contour parallel to the picture plane.** Fig. 252 *A* instead of *B* or *C*.

One of the greatest disadvantages in the use of either isometric or oblique drawing is the effect of distortion produced by the lack of convergence in the receding lines, the violation of perspective. This in some cases, particularly with large objects, becomes so painful as practically to prohibit the use of these methods. It is perhaps even more noticeable in oblique than in isometric, and of course increases with the length of the cross axis. Hence

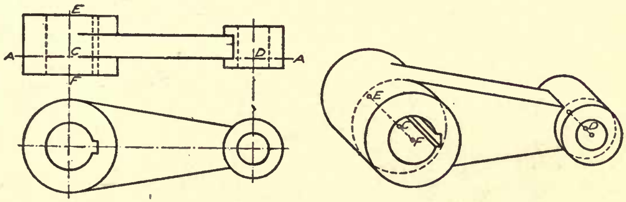
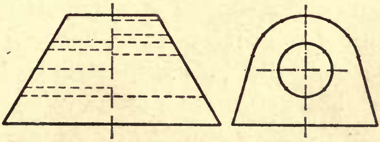


FIG. 255.

the second rule, **always have the longest dimension parallel to the picture plane.** *A* not *B* in Fig. 253.

In case of conflict between these two rules **the first should have precedence,** as the advantage of having the irregular face without distortion is greater than is gained by the second rule. Fig. 254.



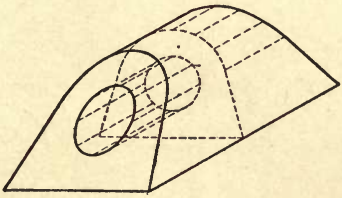


FIG. 256.—Offsets from right section.

It will be noted that so long as the front of the object is in one plane parallel to the plane of projection, the front face of the oblique projection is exactly the same as the orthographic. When the front is made up of more than one plane, particular care must be exercised in preserving the relationship by selecting one as the starting plane and working from it. In such a figure as the link, Fig. 255, the front bosses may be imagined as cut off on the plane *A-A*, and the front view, *i.e.*, the section on *A-A* drawn as the front of the oblique projection. On axes through the centers *C* and *D* the distances *CE* behind and *CF* in front may be laid off. When an object has no face perpendicular to its

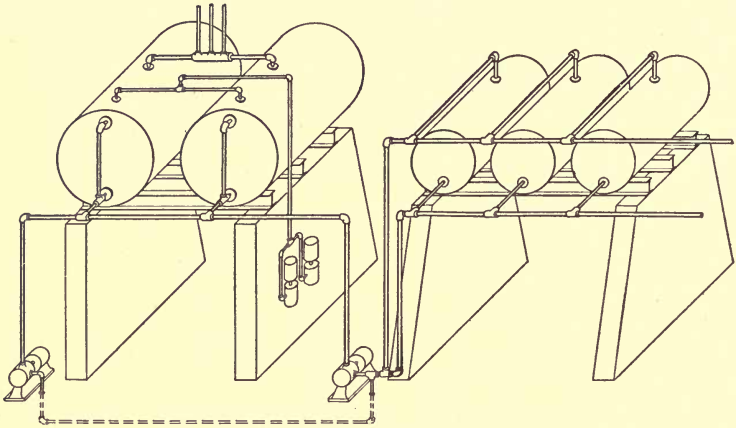


FIG. 257.—Piping system in oblique drawing.

base it may be drawn in a similar way by cutting a right section and measuring offsets from it as in Fig. 256.

This offset method, previously illustrated in the isometric drawings, Figs. 239 and 240, will be found to be a most rapid and convenient way for drawing almost any figure, and it should be studied carefully.

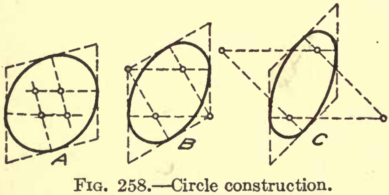


FIG. 258.—Circle construction.

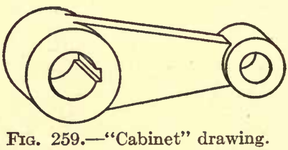


FIG. 259.—"Cabinet" drawing.

Fig. 257 is an illustration of a piping lay-out, showing the value of oblique drawing in explaining clearly what would be very difficult to represent in orthographic.

Circles in oblique drawing may either be plotted, or may be drawn approximately, on the same principle as Fig. 241, by erecting perpendiculars at the middle points of the containing square. In isometric it happens that one intersection falls in the corner of the square, and advantage is taken of the fact. In oblique its position depends on the angle of the cross axis. Fig. 258 shows three oblique squares at different angles and their inscribed circles.

Cabinet drawing is a modification of oblique projection in which all the measurements parallel to the cross axis are reduced one-half, in an attempt to overcome the appearance of excessive thickness produced in oblique drawing. The cabinet drawing Fig. 259 may be compared with the oblique drawing Fig. 255.

Axonometric Projection.

The principle of isometric projection was shown in the double revolution of the cube. A cube might be revolved into any position showing three of its faces, and the angles and proportionate foreshortening of the axes used as the basis for a system of

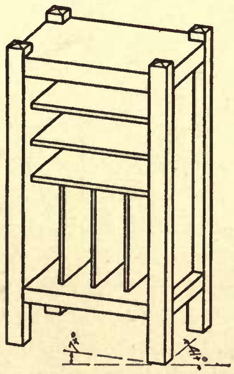


FIG. 260.—Dimetric projection.

pictorial representation, known in general as axonometric (or axometric) projection. Isometric projection is therefore simply a special case in which the axes are foreshortened equally.

Other positions which would show less distortion may be chosen, but on account of the added time and special angles necessary for their execution, are not often used.

When two axes are equal, and the third unequal, the system is sometimes called "dimetric" projection. A simple dimetric projection in which the ratios are 1:1:1/2 is shown in Fig. 260. In this position the tangents of the angles are 1/8 and 7/8, making the angles approximately 7 and 41 degrees.

A simple and pleasing system known as *clinographic* projection is used in the drawing of crystal figures in mineralogy. It is a form of oblique projection in which the figure is imagined as revolved about a vertical axis through an angle whose tangent is 1/3, then the eye (at an infinite distance) elevated through an angle whose tangent is 1/6. Fig. 261 is a graphic explanation.

(1) represents the top and front views of the three axes of a cube.

(2) is the top view revolved through $\tan^{-1} 1/3$.

(3) is the side view of (2).

(4) is a front view projected from (2) and (3), the projectors from (3) being at $\tan^{-1} 1/6$.

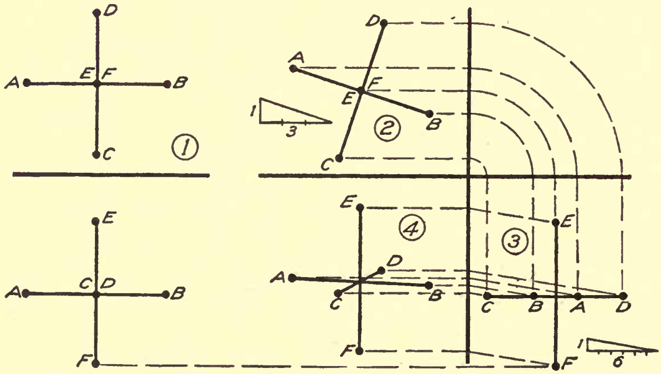


FIG. 261.—Analysis of clinographic axes.

When used in crystallography a diagram of the axes is usually constructed very accurately on card board, and used as a templet or stencil, transferring the center and terminal points by pricking through to the sheet on which the drawing is to be made. Fig. 262 shows, in stages, a method of constructing this diagram, which as will be seen is simply a combination in one view of 2 3, and 4 of Fig. 261. Take *MON* of convenient length, divide it into three equal parts, at *G* and *H*, and draw perpendiculars as shown. Make $MS = 1/2\ MO$ and draw *S′OD*. Then *CD* will be one horizontal axis.

Make $ML = 1/2\ OG$ and draw *LO*. Project the point of intersection of *LO* and *GC* back horizontally to *LM* at *A*, then *AOB* will be the other horizontal axis.

To obtain length of vertical axis make $ME' = OG$, and lay off OE and $OF = OE'$.

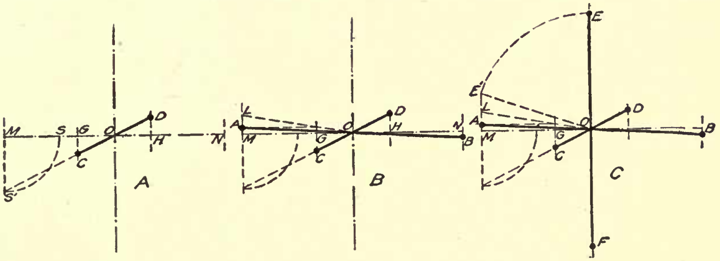


FIG. 262.—Stages of construction of clinographic axes.

The axial planes, and some crystals drawn on these axes, are shown in Fig. 263.

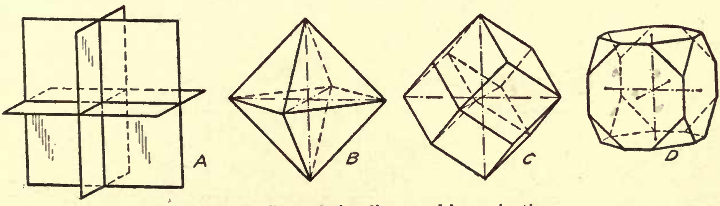


FIG. 263.—Crystals in clinographic projection.

These axes are for the isometric system of crystals. Axes for the other crystal systems may be constructed graphically in the

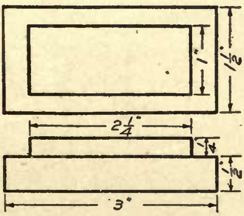


FIG. 264.

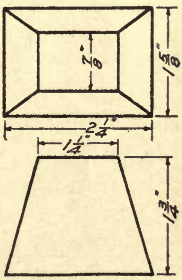


FIG. 265.

same way, by drawing their orthographic projections, revolving, and projecting to the vertical plane with oblique projectors as was done in Fig. 261.

PROBLEMS.

The following problems are intended to serve two purposes; they are given first, for practice in the various methods of pictorial representation, second, for practice in reading and translating orthographic projections.

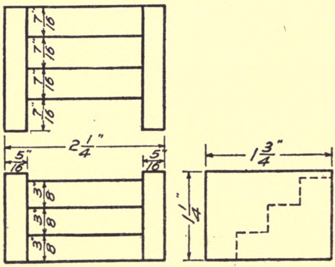


FIG. 266.

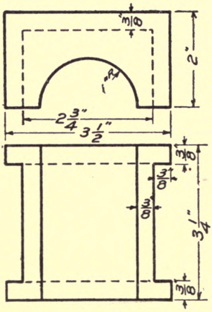


FIG. 267.

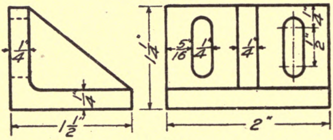


FIG. 268.

They may be drawn in a space not to exceed 4x5 inches, and are arranged in groups for convenience in selection and assignment; but any of the figures may, if desired, be drawn in one of the other methods. Some of the figures in Chapter VI may be used for a still further variety of problems in this connection.

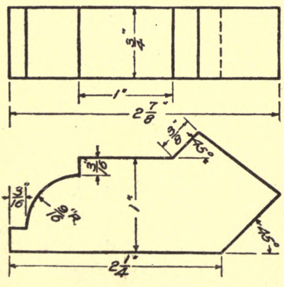


FIG. 269.

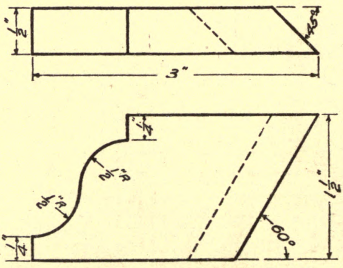


FIG. 270.

Do not show invisible lines, except when necessary to explain construction.

Group I.—Isometric Drawing:

Prob. 1. Isometric drawing of the oil-stone, Fig. 264. Full size.

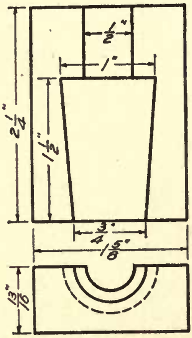


FIG. 271.

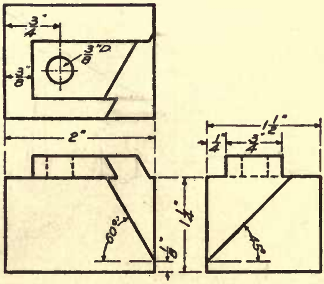


FIG. 272.

2. Isometric drawing of truncated pyramid, Fig. 265. Full size.
3. Isometric drawing of steps, Fig. 266. Full size.
4. Isometric drawing of a 1 1/2″ cube with circles on the three visible faces (approx. method).

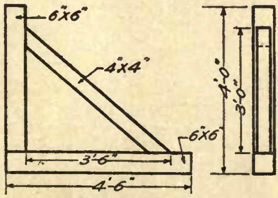


FIG. 273.

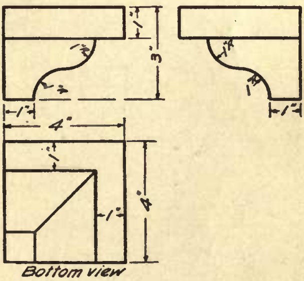


FIG. 274.

5. Isometric drawing of brass, Fig. 267. Scale 6″=1′.
6. Isometric drawing of bracket, Fig. 268. Full size.

Prob. 7. Isometric drawing of brick, Fig. 269. Full size.

8. Isometric drawing of brick, Fig. 270. Full size.

9. Isometric drawing of core box, Fig. 271. Full size.
10. Isometric drawing of block, Fig. 272. Full size.
11. Isometric drawing of knee brace, Fig. 273. Scale 1/2″=1′.

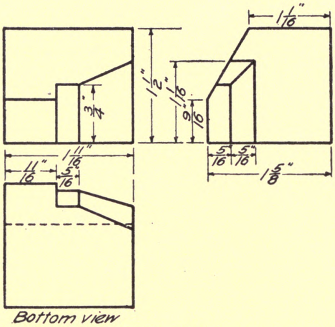


Fig. 275.

12. Isometric drawing of mitered corner (face return), Fig. 274; axes reversed to show under side. Scale 6″=1′.
13. Isometric drawing of stone (springing stone of plate band, or flat arch) Fig. 275, axes reversed. Full size.

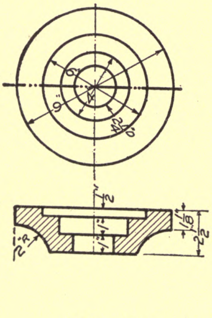


Fig. 276.

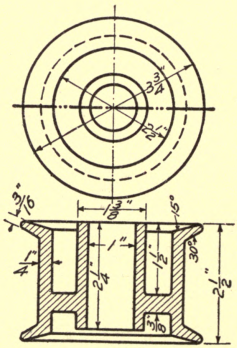


Fig. 277.

Group II.—Isometric Sections:

Prob. 14. Isometric section of cap, Fig. 276. Scale 3″=1′.

15. Isometric section of pulley, Fig. 277. Scale 6″=1′.

16. Isometric half-section of cone, Fig. 278. Scale 6″=1′.
17. Isometric half-section of gland, Fig. 279. Scale 6″=1′.

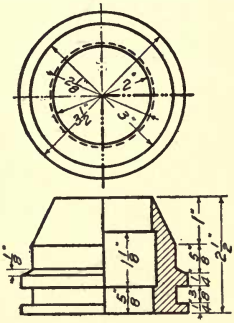


Fig. 278.

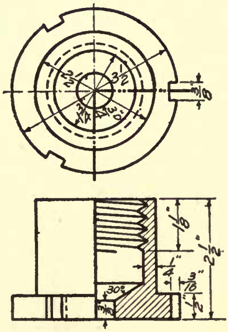


Fig. 279.

Group III.—Oblique Drawing:

Prob. 18. Oblique drawing of block, Fig. 280, 30 degrees to the left. Full size.

19. Oblique drawing of block, Fig. 281, 30 degrees to the right, full size.
20. Oblique drawing of grindstone, Fig. 282, 45 degrees to the right. Scale 1″=1′.

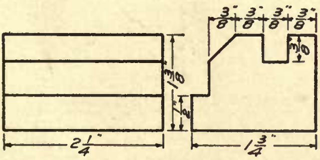


Fig. 280.

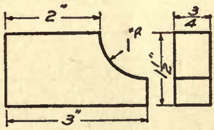


Fig. 281.

21. Oblique drawing of 1 1/2″ cube, 30 degrees to the right, with circles on the three visible faces (approximate).
22. Oblique drawing of 1 1/2″ cube, 45 degrees to the left, with circles on three visible faces (approximate).
23. Oblique drawing of column section, Fig. 283, 30 degrees to the left. Scale 1 1/2″=1′.
24. Oblique drawing of monument, Fig. 284, 30 degrees to the right. Scale 1/2″=1′.

25. Oblique drawing of gland, Fig. 285, 45 degrees to the right. Full size.
26. Oblique drawing of angle brace, Fig. 286, 30 degrees to the left. Scale 6″=1′.

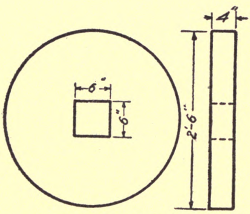


Fig. 282.

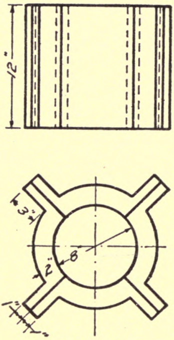


Fig. 283.

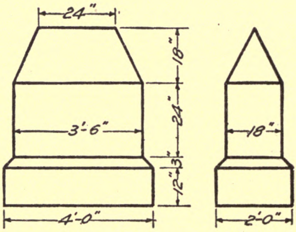


Fig. 284.

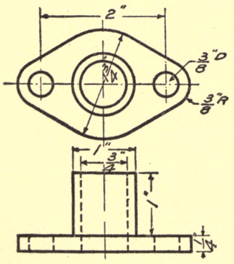


Fig. 285.

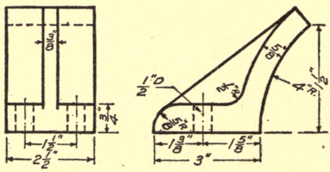


Fig. 286.

27. Oblique drawing of slotted link, Fig. 287, 30 degrees to the left. Scale 1 1/2″=1′.
28. Oblique drawing of bell-crank, Fig. 288, 45 degrees to the left. Scale 6″=1′.

29. Oblique drawing of link, Fig. 289, 30 degrees to the right. Full size.

30. Oblique drawing of cap, Fig. 290, 45 degrees to the left. Scale 6″=1′.

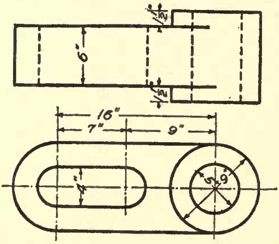


Fig. 287.

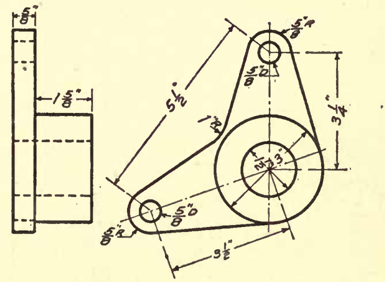


Fig. 288.

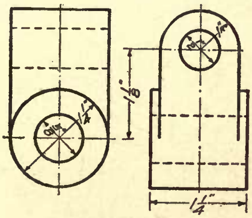


Fig. 289.

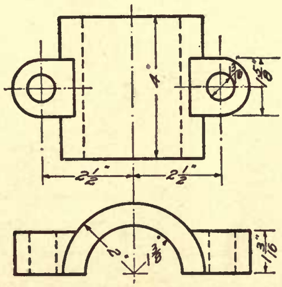


Fig. 290.

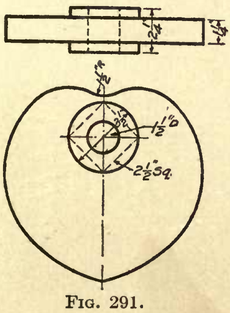


Fig. 291.

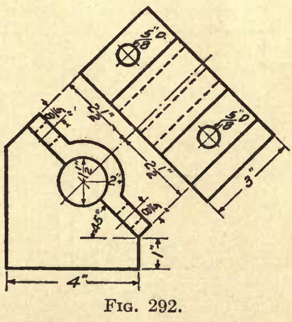


Fig. 292.

31. Oblique drawing of cam, Fig. 291, 30 degrees to the right. Scale 3″=1′.

32. Oblique drawing of bearing. Fig. 292, 30 degrees to the right. Scale 6″=1′.

33. Oblique drawing of moulded brick and face return, Fig. 293, 45 degrees to the right, axes reversed to show under side. Scale 3″=1′.

34. Oblique drawing of culvert arch, Fig. 294, 30 degrees to the left, draw by offsets from right section. Full size.

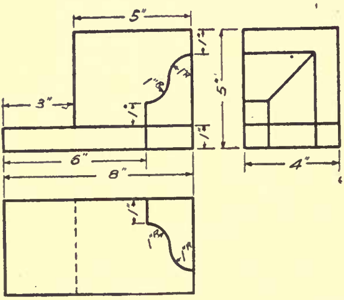


FIG. 293.

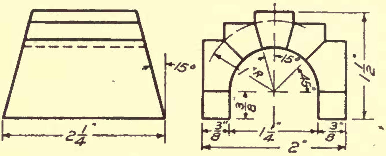


FIG. 294.

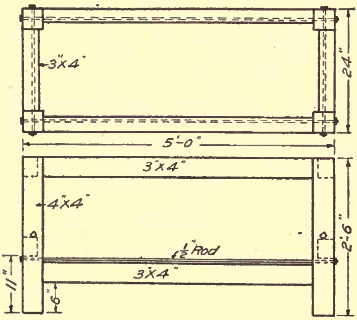


FIG. 295.

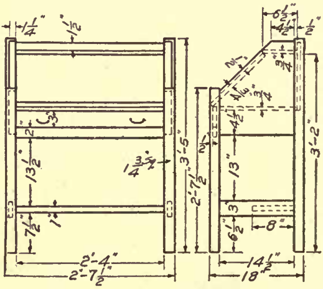


FIG. 296.

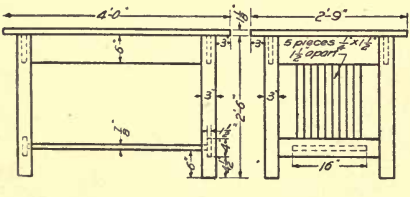


FIG. 297.

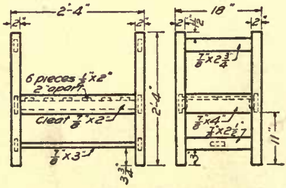
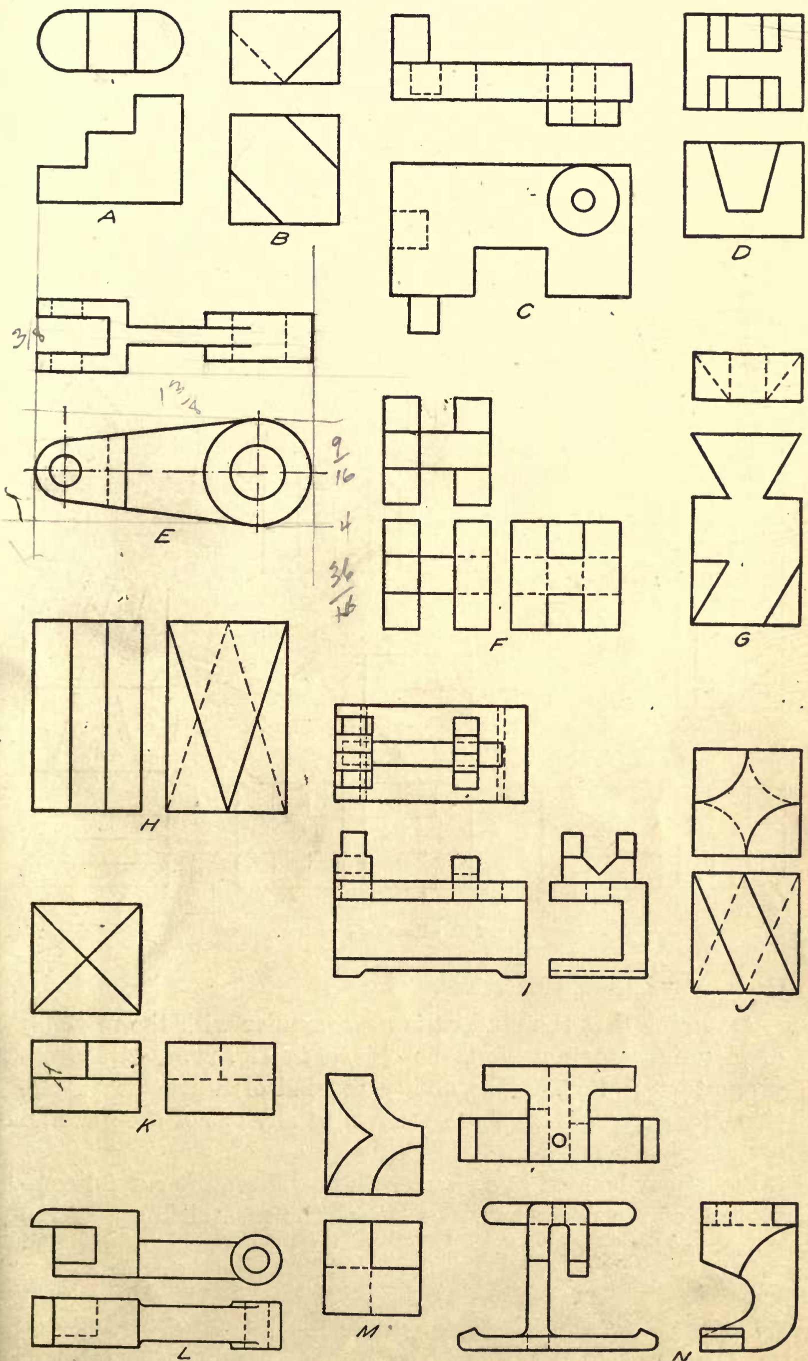


FIG. 298.

Group IV.—Cabinet and Dimetric Projection.

Prob. 35. Cabinet projection of frame, Fig. 295. Scale 3/4″=1′.


A
B
C
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36. Cabinet projection of desk, Fig. 296. Scale 1″=1′.
37. Dimetric Projection of table, Fig. 297. Scale 3/4″=1′.
38. Dimetric projection of Roman chair, Fig. 298. Scale 1″=1′.

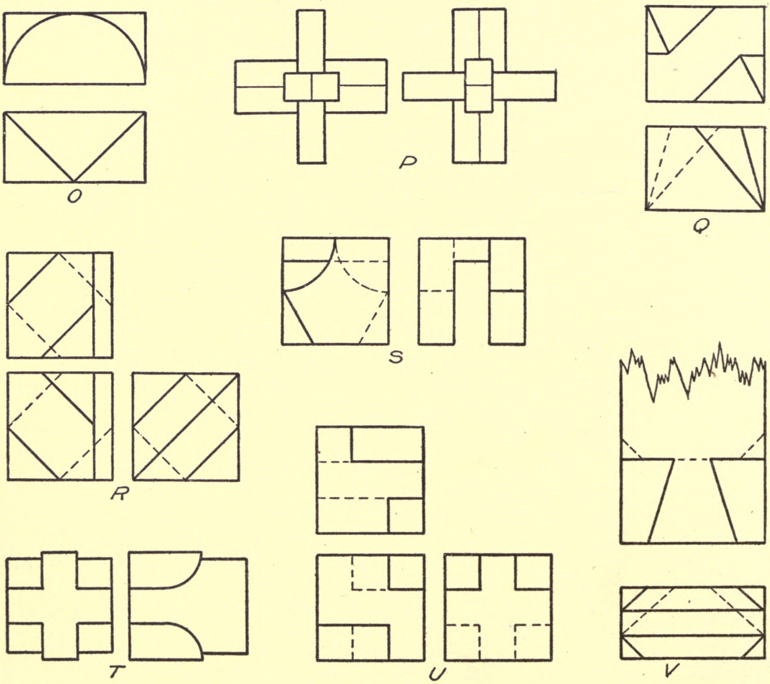


Fig. 300.—Reading exercises.

Group V.—Reading Exercises.

Assuming that the student is now familiar with the methods of pictorial representation, the objects in Fig. 299 and 300 are given to test further the ability to read orthographic projections, by sketching the figures shown, in any one of the pictorial systems.

Some may be read at a glance, others will require careful comparison of the different views before the mental image of the object is clearly defined.

CHAPTER IX.

Working Drawings.

A working drawing is a drawing that gives all the information necessary for the complete construction of the object represented.

It will thus include: (1) The full graphical representation of the shape of every part of the object. (2) The figured dimensions of all parts. (3) Explanatory notes giving specifications in regard to material, finish, etc. (4) A descriptive title.

Although isometric, oblique and cabinet drawing are used to some extent in special cases, the basis of practically all working drawing is orthographic projection. To represent an object completely, at least two views would be necessary, often more. The only general rule would be, make as many views as are necessary to describe the object, **and no more.**

Instances may occur in which the third dimension is so well understood as to make one view sufficient, as for example in the drawing of a shaft or bolt. In other cases perhaps a half dozen views might be required to show the piece completely. Some thought will be involved as to what views will show the object to the best advantage; whether an auxiliary view will save one or more other views, or whether a section will better explain the construction than an exterior view. One statement may be made with the force of a rule—If anything in clearness may be gained by the violation of any one of the strict principles of projection, violate it.

This statement is of sufficient importance to warrant several examples, although there is no guide but the draftsman's judgment as to when added clearness might result by disregarding a theoretical principle.

If a six-arm wheel, Fig. 301, be shown in section as if cut by a plane *A–A*, the true projection would be as *A;* if cut by a plane *B–B* the true projection would be as *B*. Neither of these would be good practical working drawings, the first does not show the true size of the arm, the second is misleading. The sectional view whether taken on *A–A* or *B–B* would be better if made as *C*.

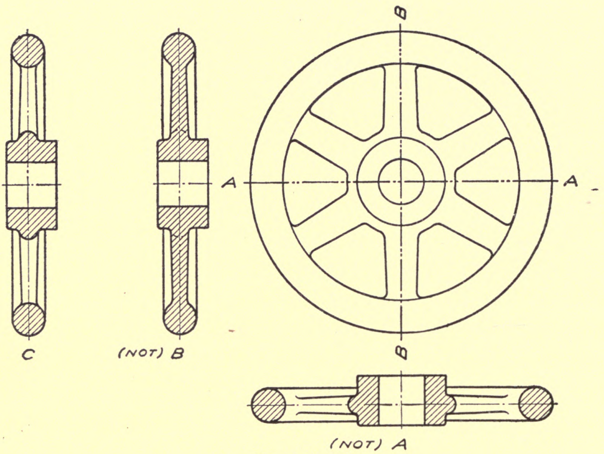


Fig. 301.

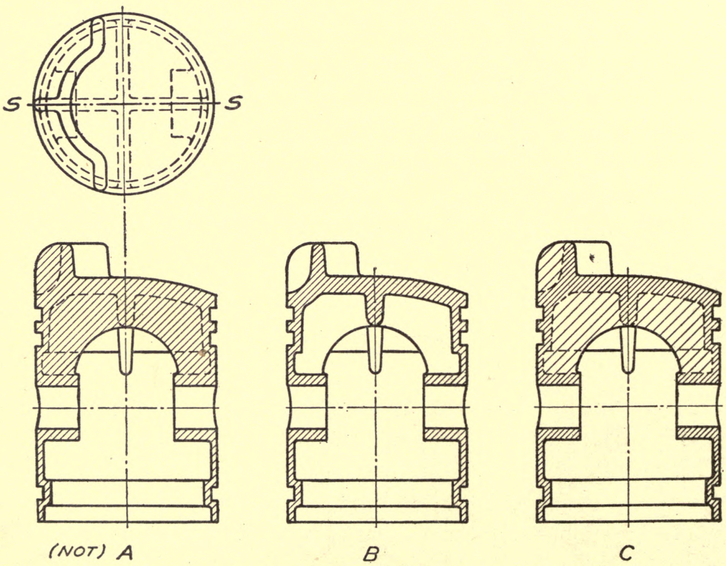


Fig. 302.—Section through a rib.

Similarly, if a section taken through a rib, as the section *S–S* of the piston, Fig. 302, is cross-hatched as in *A* the effect is misleading. Its character may be indicated much better by omitting the lining on the rib, as if the section were just in front of it, as at *B*, or by running every other line across the rib section, as at *C*.

Often a true section would give an unsymmetrical appearance to the drawing of a symmetrical piece. In such cases principle should be violated to preserve the effect of symmetry. Fig. 303 is an illustration.

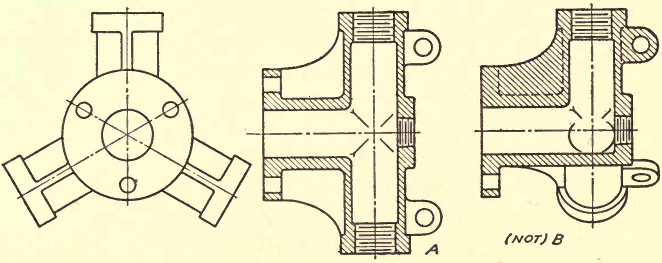


FIG. 303.—A symmetrical section.

Classes of Working Drawings.

Working drawings may be divided into two general classes, assembly drawings and detail drawings.

An assembly drawing or general drawing is, as its name implies, a drawing of the machine or structure showing the relative positions of the different parts.

A detail drawing is the drawing of a separate piece or group of pieces, giving the complete description for the making of each piece. In a very simple machine the assembly drawing may be made to serve as a detail drawing by showing fully the form and dimensions of each part composing it.

Under the general term *assembly drawing* would be included preliminary design drawings and layouts, piping plans, and final complete drawings used for assembling or erecting the machine or structure.

The *design drawing* is the preliminary layout, full size if possible, on which the scheming, inventing, and designing is worked out accurately after freehand sketches have determined the general ideas. From it the detail drawings of each piece are made. The design drawing may be finished and traced to form the assembly drawing, or the assembly drawing may be drawn from it, perhaps to smaller scale to fit a standard sheet.

The assembly drawing would give the over-all dimensions, the distances from center to center or from part to part of the different pieces, indicating their location and relation so that the machine could be erected by reference to it.

The **grouping** of the details is entirely dependent upon the requirements of the shop system. In a very simple machine and if only one or two are to be built, all the details may perhaps be grouped on a single sheet. If many are to be built from the same design, each piece may have a separate sheet. In general, it is a good plan to group the parts of the same material or character. Thus forgings may be grouped on one sheet, bolts and screws on another.

A complete **set** of working drawings therefore consists of assembly sheets, and detail sheets for each of the classes of workmen, as the patternmaker, blacksmith, machinist, etc. These special drawings need not include dimensions not needed by those trades. The set may include also drawings for the purchaser.

There is a "*style*" in drawing, just as there is in literature, which in one way indicates itself by the ease of reading. Some drawings "stand out," while others which may contain all the information are difficult to decipher. Although dealing with "mechanical thought," there is a place for some artistic sense in mechanical drawing. The number, selection, and disposition of views, the omission of anything unnecessary, ambiguous, or misleading, the size and placing of dimensions and lettering, and the contrast of lines are all elements concerned in the *style*.

Order of Penciling.

In penciling a working drawing the order should be as follows: first, lay off the sheet to standard size, with border (1/2 inch), and block out space for the title; second, plan the arrangement by making a little preliminary freehand sketch, guessing roughly at the space each figure will occupy, and placing the views to the best advantage for preserving if possible a balance in the appearance of the sheet; third, draw the center lines for each view, and on these lay off the principal dimensions. In Chapter VI the general principle was given that the view showing the characteristic shape should be made first. The different projections should however be carried on together and no attempt made to finish one view before drawing another. Fourth, finish the projections, putting in minor details last; fifth, draw the necessary dimension lines and add the dimensions; sixth, lay off the title; seventh, check the drawing carefully.

Fig. 304 illustrates the stages of penciling a drawing. Overlapping and overextending pencil marks should not be erased

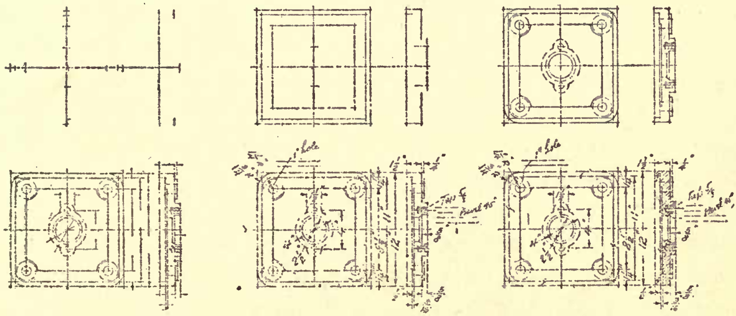


FIG. 304.—Stages of penciling.

until after the drawing has been inked. These extensions are often convenient in preventing the overrunning of ink lines. All unnecessary erasing should be avoided as it abrades the surface of the paper so that dirt catches more readily.

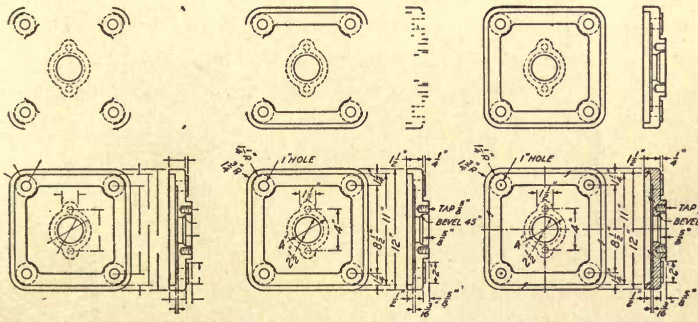


FIG. 305.—Stages of inking.

Order of Inking.

First, ink all circles, then circle arcs; second, ink the straight lines in the order,—horizontal, vertical, inclined; third, ink center lines; extension and dimension lines; fourth, ink the dimensions; fifth, section line all cut surfaces; sixth, ink notes, title, and border line; seventh, check the tracing. Figure 305 shows the stages of inking.

DIMENSIONING.

After the correct representation of the object by its projections, the entire value of the drawing as a working drawing lies in the dimensioning. Here our study of drawing as a language must be supplemented by a knowledge of the shop methods which will enter into the construction. The draftsman to be successful must have an intimate knowledge of pattern making, forging, sheet metal working and machine shop practice.

The dimensions put on a drawing are not those which were used in making it, but those necessary and most convenient for the workman who is to make the piece. The draftsman must thus put himself in the place of the pattern maker, blacksmith or machinist, and mentally construct the object represented, to see if it can be cast or forged or machined practically and economically, and what dimensions would give the required information in the best way. In brief, the drawing must be made with careful thought of its purpose.

General Rules for Dimensioning.

In the alphabet of lines in Fig. 62 the dimension line was shown as a fine full line, with long arrow heads whose extremities indicate exactly the points to which the dimension is taken, and having a space left for the figure.

Some practice uses a long dash line, and some a red line for dimension lines. It is common practice among structural draftsmen to place the dimension above the continuous line as in Fig. 346, but it is not recommended for machine or architectural work.

Dimensions of course always indicate the finished size of the piece, without any reference to the scale of the drawing.

Dimensions should read from the bottom and right side of the sheet, no matter what part of the sheet they are on.

Dimensions up to 24″ should always be given in inches. An exception is again noted in structural practice. Over 24″ practice varies, but the majority use feet and inches. The sizes of wheels, gears, pulleys and cylinder bores, the stroke of pistons, and the length of wheel bases are always given in inches; and sheet metal work is usually dimensioned in inches.

Feet and inches are indicated thus 5′–6″ or 5 ft.–6″. When there are no inches, it should be indicated as 5′–0″, 5′–0½″.

Fractions must be made with a horizontal line as $2\frac{1}{4}''$, $3\frac{1}{16}''$.

The diameter of a circle should be given, not the radius.

In general give dimensions from center lines, never from the edge of a rough casting.

Have figures large enough to be easily legible. In an effort for neatness the beginner often gets them too small.

Radii of arcs should be marked R or Rad.

Dimensions should generally be placed between views.

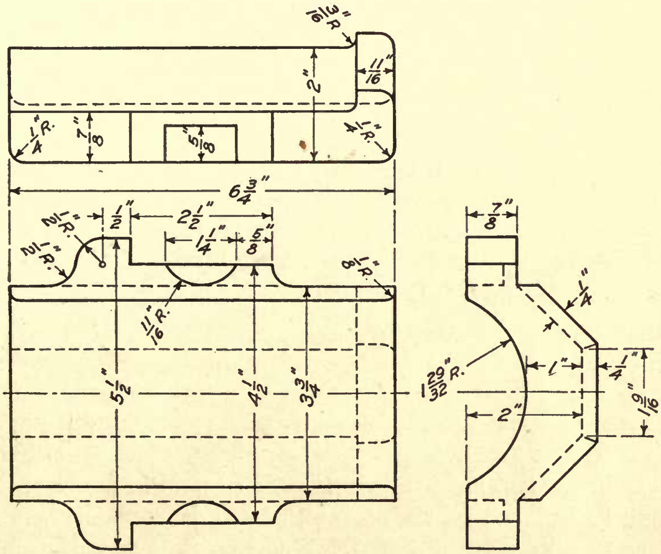


Fig. 306.—Example of dimensioning.

In general do not repeat dimensions on adjacent views.

Preferably keep dimensions outside the figure unless added clearness, simplicity, and ease of reading the drawing will result from placing them in the figure. See Fig. 306. Keep them off sectioned surfaces if possible.

Extension lines should not touch the outline.

Always give an over-all dimension. Never require the workman to add or subtract figures.

Never use any center line as a dimension line.

Never put a dimension on a line of the drawing.

A dimension not agreeing with the scaled distance, or which has been changed after the drawing has been made should be heavily underscored as in Fig. 307 (2), or marked as in (3).

Dimensions must never be crowded. If the space is small, methods as illustrated in Fig. 307 (4) (5) (6) (9), etc., may be used.

The direction in which a section is taken should be indicated by arrows on the line representing the cutting plane, as in (29).

If it is possible to locate a point by dimensions from two center lines, do not give an angular dimension.

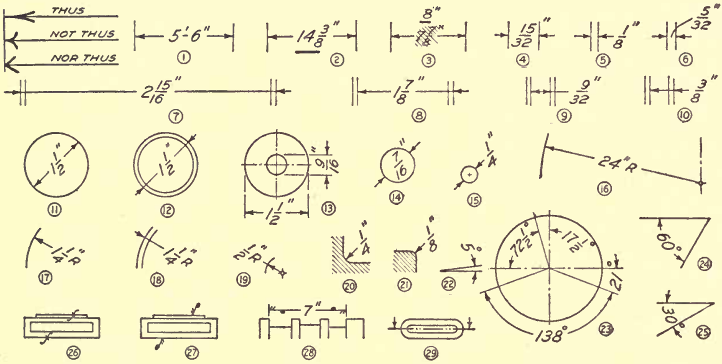


FIG. 307.—Dimensions.

The Finish Mark.

Several methods are used for indicating that certain parts are to be machined, and that allowance must therefore be made on the casting or forging for finish. The symbol in common use is a small "f" placed on the surface, on the view which shows the surface as a line, Fig. 307 (26). If the piece is to be finished all over, the note "f. all over" is placed under it, and the marks on the drawing omitted.

Another finish mark, proposed by Professor Follows for adoption as a standard, is shown at (27). It has a distinct individuality, and, by pointing to the line instead of crossing it, does not mar the appearance of the drawing as the "f" does. The symbol as used in (28) indicates that the entire surface between the extension lines is to be finished.

Some elaborate symbols for different kinds of finish have been devised, but it is much better to specify these in words.

Notes and Specifications.

Some necessary information cannot be drawn, and hence must be added in the form of notes. This would include the number required of each piece, the kind of material, kind of finish, kind of fit (as force fit, drive fit, etc.), and any other specifications as to its construction or use.

Do not be afraid of putting notes on drawings. Supplement the graphic language by the English language whenever added information can be conveyed, but be careful to word it so clearly that the meaning cannot possibly be misunderstood.

If a note as to the shape of a piece will save making a view, use it.

If two pieces are alike, but one "right-hand" and the other "left-hand," one only is drawn and a note added 1–R. H., 1–L. H.

Standard bolts and screws are never detailed, but are specified in the bill of material.

The bill of material is a tabulated statement placed on a drawing, or in some cases, for convenience, on a separate sheet, which gives the mark, name, number wanted, size, material, pattern number, and sometimes the weight, of each piece. A column giving the over-all dimensions of the piece when crated or boxed for shipping is sometimes added, particularly in manufactures for foreign shipment. A final column is usually left for "remarks."

Fig. 308 is a detail drawing illustrating the use of the bill of material.

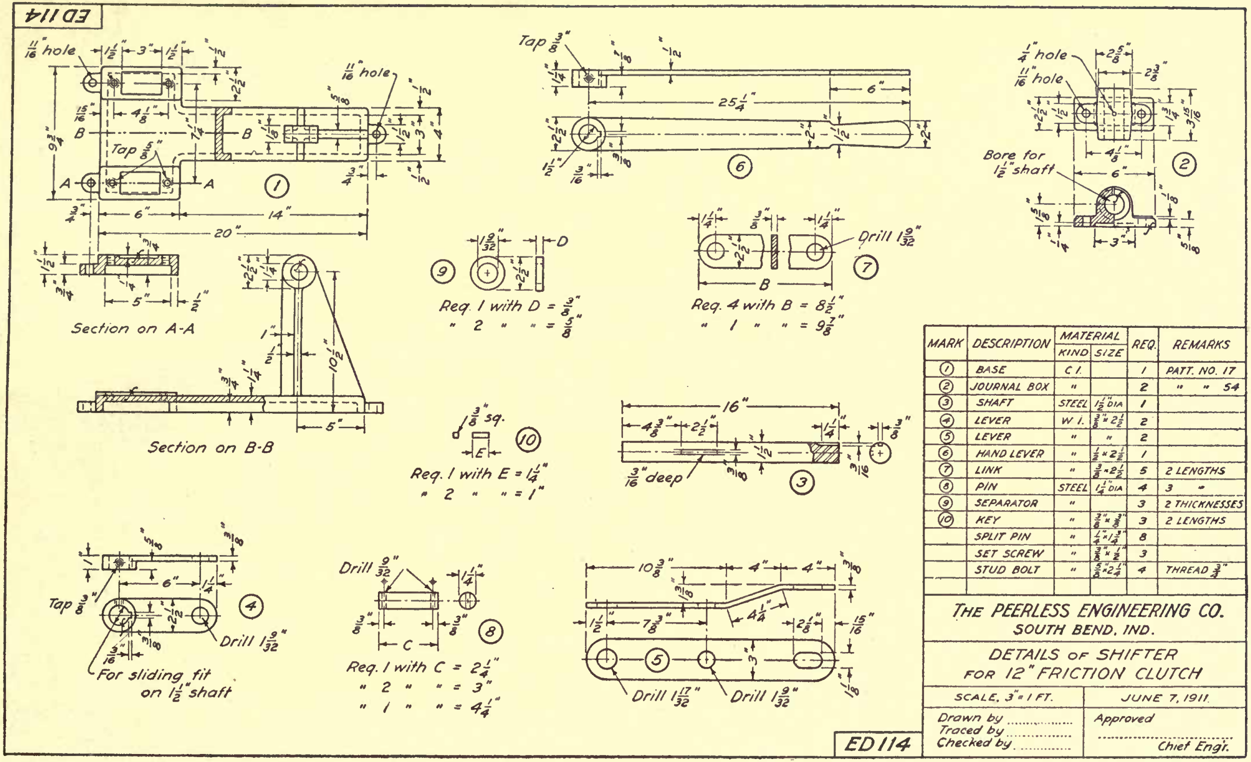
Title.*

The title to a working drawing is usually boxed in the lower right hand corner, the size of the space varying of course with the size of the drawing. For 12″x18″ sheets the space reserved may be about three inches long. For 18″x24″ sheets four or four and a half, and for 24″x36″ sheets five or five and a half inches.

A form of title which is growing in favor is the record strip, a narrow strip marked off entirely across the lower part of the sheet, containing the information required in the title, and ample space for the record of orders, changes, etc. Fig. 309 illustrates this form.

It is sometimes desired to keep records of orders and other private information on the tracing, but not have them appear

*For a full discussion of titles for different classes of drawings see "The Essentials of Lettering," from which this paragraph is condensed.



MARK	DESCRIPTION	MATERIAL KIND	MATERIAL SIZE	REQ.	REMARKS
1	BASE	C.I.		1	PATT. NO. 17
2	JOURNAL BOX	"		2	" " 54
3	SHAFT	STEEL	1½" DIA	1	
4	LEVER	W.I.	3/8" × 2½	2	
5	LEVER	"	"	2	
6	HAND LEVER	"	½ × 2½	1	
7	LINK	"	3/8 × 2½	5	2 LENGTHS
8	PIN	STEEL	1¼" DIA	4	3 "
9	SEPARATOR	"		3	2 THICKNESSES
10	KEY	"	3/8" × 3/8"	3	2 LENGTHS
	SPLIT PIN	"	¼" × 1¾"	8	
	SET SCREW	"	3/8" × ½"	3	
	STUD BOLT	"	5/8" × 2¼"	4	THREAD ¾"

FIG. 308.—Detail, drawing with bill of material.

on the print. In such case both the corner title and record strip are used, and the record strip trimmed off the print before sending it out.

Contents of Title.

In general the title of a machine or structural drawing should contain:

(1) Name of machine or structure.
(2) General name of parts (or simply "details").

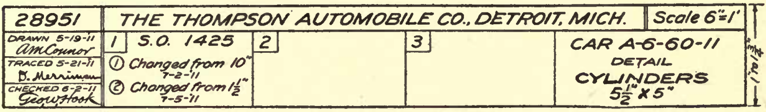


Fig. 309.—A record strip.

(3) Name of purchaser, if special machine.
(4) Manufacturer; company or firm name and address.
(5) Date; usually date of completion of tracing.
(6) Scale or scales; desirable on general drawings, often omitted from fully dimensioned detail drawings.
(7) Drafting room record; names, initials or marks of the draftsman, tracer, checker, approval of chief draftsman, engineer or superintendent.

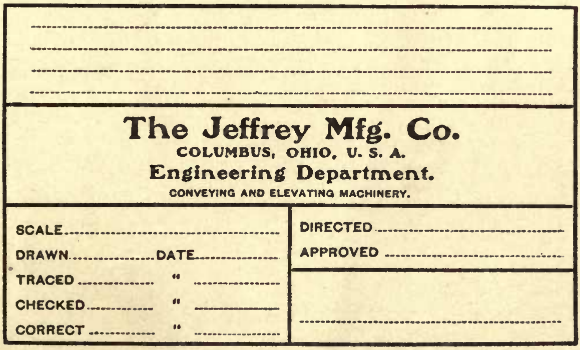


Fig. 310.—A printed title form.

(8) Numbers; of the drawing, of the order. The filing number is often repeated in the upper left hand corner upside down, for convenience in case the drawing should be reversed in the drawer.

The title should be lettered freehand in single stroke capitals, either upright or inclined, but never both styles in the same title.

Any revision or change in the drawing should be noted, with date, in the title or record strip.

Every drafting room has its own standard form for titles. In large offices this is often printed in type on the tracing cloth. Figs. 310 and 311 are characteristic examples.

Sometimes a title is put on with a rubber stamp, and inked over while wet.

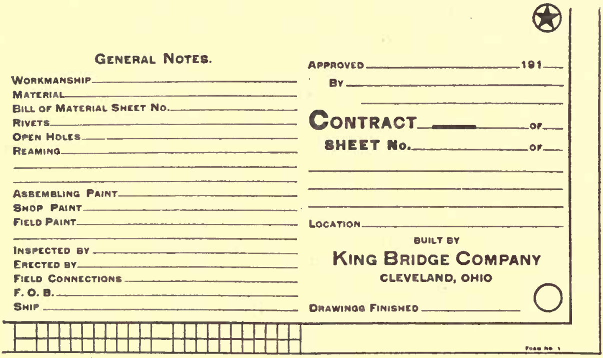

GENERAL NOTES.
WORKMANSHIP
MATERIAL
BILL OF MATERIAL SHEET NO.
RIVETS
OPEN HOLES
REAMING
ASSEMBLING PAINT
SHOP PAINT
FIELD PAINT
INSPECTED BY
ERECTED BY
FIELD CONNECTIONS
F. O. B.
SHIP
APPROVED 191
BY
CONTRACT OF
SHEET NO. OF
LOCATION
BUILT BY
KING BRIDGE COMPANY
CLEVELAND, OHIO
DRAWINGS FINISHED

FIG. 311.—A printed title form.

In commercial drafting, accuracy and speed are the two requirements. The drafting room is an expensive department, and time is an important element. The draftsmen must therefore have a ready knowledge not only of the principles of drawing, but of the conventional methods and abbreviations, and any device or system that will save time without sacrificing effectiveness, is desirable.

FASTENINGS.

In every working drawing will occur the necessity of representing the methods of fastening parts together, either with permanent fastenings (rivets) or with removable ones (bolts, screws and keys), and the draftsman must be thoroughly familiar with the conventional methods of their representation.

The Helix.

A helix is the line of double curvature generated by a point moving uniformly along a straight line while the line revolves uniformly about another line, as an axis.

The distance advanced parallel to the axis in one revolution is called the pitch. If the moving line is parallel to the axis it will generate a cylinder, and the word "helix" alone always means a cylindrical helix. If the moving line intersects the axis (at an angle less than 90 degrees) it will generate a cone and the curve made by the moving point will be a conical helix. When the angle becomes 90 degrees the helix degenerates into a spiral.

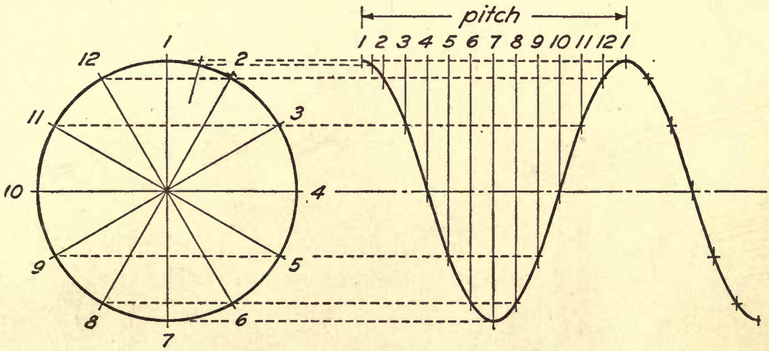


FIG. 312.—Construction of the helix.

To Draw a Helix.—Divide the circle of the base of the cylinder into a number of equal parts, and the pitch into the same number. As the point revolves through one division it will advance one division of the pitch, when half way around the cylinder it will have advanced one-half the pitch. Thus the curve may be found by projecting the elements represented by the divisions of the circle, to intersect lines drawn through the corresponding divisions of the pitch, as in Fig. 312.

The conical helix is drawn similarly, the pitch being measured on the axis.

Screw Threads.

The helix is the curve of the screw thread, but is not often drawn, and only with screws of large diameter. Fig. 313 illustrates its application on a square thread screw and section of nut. Two helices of the same pitch but different diameters are required, one for the tip and one for the root of the thread. If many threads are to be drawn, a templet may be made, by laying off the projection of the helix on a piece of cardboard, and cutting out with a sharp knife.

Fig. 314 shows the method of drawing a helical spring with round section, by constructing the helix of the center line of the

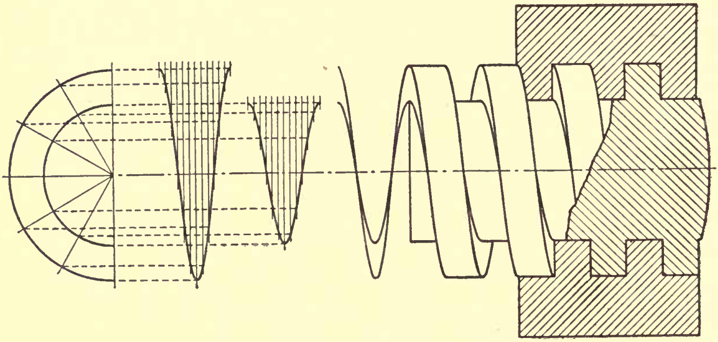


FIG. 313.—Construction of square thread.

section, drawing on it a number of circles of the diameter of the stock, and drawing an envelope curve tangent to the circles.

Forms of Threads.

Screws are used for fastenings, for adjustment, and for transmitting power or motion. For these different purposes several different forms of thread are in use. The *United States Standard*

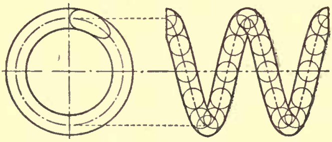


FIG. 314.

(sometimes called the Franklin Institute, and Sellers standard), Fig. 315, *A*, is the commonest, and in this country is the form intended when not otherwise specified. It is a V thread at 60 degrees with the tip flattened one-eighth of its height, which lessens the liability of its being injured, and the root filled the same amount, thus increasing the strength of the bolt. In drawing, these flats need not be represented.

The *sharp V* at 60 degrees is still used, although it has little to recommend it. The *square thread* and the *Acme* or Powell thread are used mainly to transmit motion. Other forms shown are the *buttress, knuckle,* and *Whitworth,* the English standard.

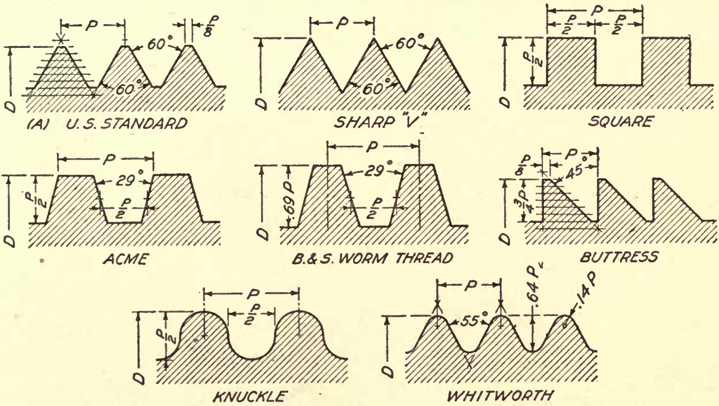


FIG. 315.—Forms of screw threads.

Threads are always understood to be single and right hand unless otherwise specified.

A right hand thread advances away from the body when turned clockwise. A left hand thread is always marked plainly "L H," and is quickly recognized also by the direction of slant.

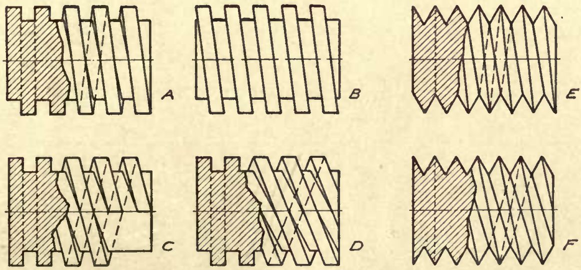


FIG. 316.—Conventional threads.

A **single thread** has one thread, of whatever section, winding around the cylinder. When it is desired to give a more rapid advance without using a coarser thread, two or more threads are wound together, side by side, giving **double** and **triple** threads. as illustrated in Fig. 316, *C and D.*

Conventional Representation of Threads.

For ordinary practice the labor of drawing the exact curves of threads is altogether unnecessary, and the helix is conventionalized into a straight line. The square thread screw would thus

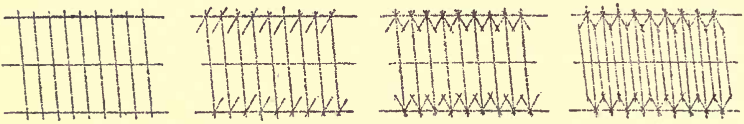


FIG. 317.—Stages in drawing *V* threads.

be drawn as in Fig. 316 (*A*) or (*B*), which while not so realistic or pleasing as Fig. 313, requires very much less time.

The V thread would be drawn, both in pencil and ink, in the stages shown in Fig. 317.

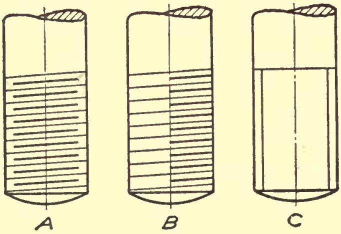


FIG. 318.

For screws less than perhaps one inch in diameter, the thread shapes are omitted and one of the conventional forms of Fig. 318 used. *A* is a very common convention. The lines are drawn with a *slight* slant (one-half the pitch), and spaced by eye. The

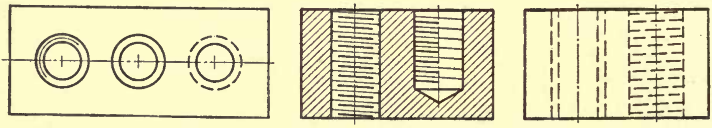


FIG. 319.—Tapped holes.

spacing need not be to the correct pitch, but to look well should somewhat approximate it.

The root lines are usually made heavier, for effect. The beginner's usual mistake of exaggerating the slant must be carefully guarded against. It is a question as to whether there is any necessity of slanting the lines at all, and in much good practice they are drawn straight across.

B is a simpler convention, in that it requires no pencil lines for limiting the root lines, as there is always a center line already drawn. In this the root lines are always placed on the shade side.

C is a convention that does not look like a thread, but that can be made rapidly, and is understood by all workmen.

Fig. 319 shows the conventional representation of tapped holes in plan, section and elevation. In showing a tapped hole

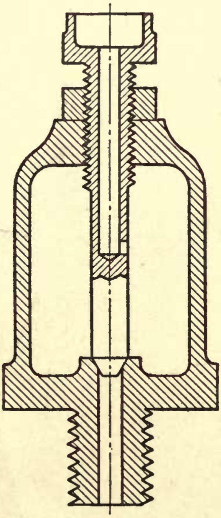


FIG. 320.

in section the slant of the thread lines would evidently be reversed as the part represented fits the invisible side of the screw. In tapped holes not extending through the piece, the "drill point," or shape of the bottom of the hole should always be shown.

When two pieces fitted together are shown in section the threads must be drawn, as in Fig. 320. The same is true for a male thread in section.

It is not necessary to draw the threads on the whole length of a long threaded shaft. They may be started at each end, and "ditto" lines used in the space between.

Dimensioning Threads.

If a thread is U. S. Standard the only dimensions given are the outside diameter and the length. When these dimensions are given the thread is always assumed to be U. S. Standard right hand, and the machinist knows the pitch, drill sizes, etc. The word "pitch" has been defined as the distance between threads. A commonly accepted meaning among machinists is the number of threads per inch, thus "8 pitch" would mean eight threads per inch. There is very little danger of misunderstanding in these two meanings, but it may be safer, particularly in screws of large diameter, to say "...... threads per in."

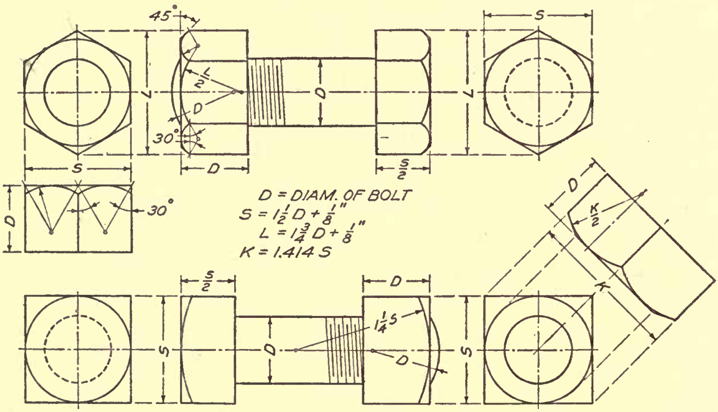


FIG. 321.—U. S. Standard bolts (unfinished).

With double and triple threads "pitch" is generally accepted to mean the distance between adjacent threads, and the distance advanced in one revolution is called the "lead."

A distinction in designation should be made between tapped holes and threaded holes.

Bolts and Nuts.

There are adopted sizes for standard hexagonal and square bolt heads and nuts, hence on a standard bolt no dimensions are placed except the diameter, length (under the head to tip of point), and length of threaded part. As there is so frequent necessity for the representation of bolts and screws the draftsman must be able to draw them without reference to tables or measurement.

Fig. 321 shows the U. S. Standard hex. head, and the standard square head bolt and nut. In drawing a hex. head three faces are shown, and in a square head, one face.

DIMENSIONS OF U. S. STANDARD BOLTS AND NUTS.

Diam. of bolt	Thrd's per inch	Distance across flats	Distance across corners		Thickness		Area at root of thread
			Hexagon	Square	Nut	Head	
1/4"	20	1/2"	37/64"	23/32"	1/4"	1/4"	.026
5/16"	18	19/32"	11/16"	27/32"	5/16"	19/64"	.045
3/8"	16	11/16"	51/64"	31/32"	3/8"	11/32"	.068
7/16"	14	25/32"	29/32"	1 7/64"	7/16"	25/64"	.093
1/2"	13	7/8"	1 1/64"	1 1/4"	1/2"	7/16"	.126
9/16"	12	31/32"	1 1/8"	1 3/8"	9/16"	31/64"	.162
5/8"	11	1 1/16"	1 15/64"	1 1/2"	5/8"	17/32"	.202
3/4"	10	1 1/4"	1 29/64"	1 25/32"	3/4"	5/8"	.302
7/8"	9	1 7/16"	1 43/64"	2 1/32"	7/8"	23/32"	.420
1"	8	1 5/8"	1 7/8"	2 19/64"	1"	13/16"	.550
1 1/8"	7	1 13/16"	2 3/32"	2 9/16"	1 1/8"	29/32"	.693
1 1/4"	7	2"	2 5/16"	2 53/64"	1 1/4"	1"	.889
1 3/8"	6	2 3/16"	2 17/32"	3 3/32"	1 3/8"	1 3/32"	1.054
1 1/2"	6	2 3/8"	2 3/4"	3 23/64"	1 1/2"	1 3/16"	1.293
1 3/4"	5	2 3/4"	3 3/16"	3 57/64"	1 3/4"	1 3/8"	1.744
2"	4 1/2	3 1/8"	3 39/64"	4 27/64"	2"	1 9/16"	2.302

A quick method of penciling a standard hex. head or nut is shown in stages in Fig. 322. Mark a point on the center line at

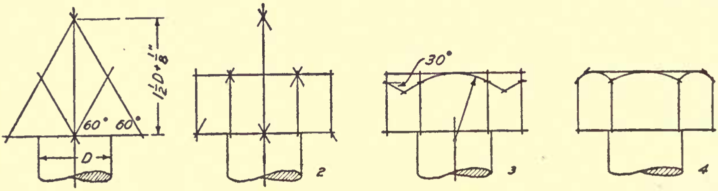


Fig. 322.—A method of drawing a hexagonal head.

a distance 1 1/2 D+1/8″. Sixty-degree lines drawn from this point to the base will give points for the outside corners. The remainder of the construction is evident from the figure.

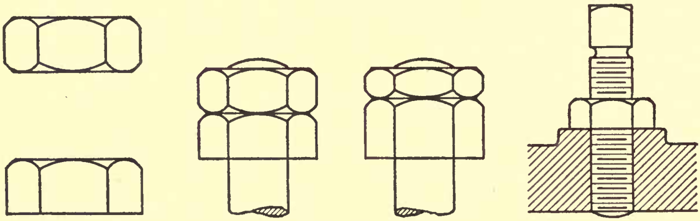


Fig. 323.—Locknuts.

It is evident from geometry that the projected width of the inclined face is one half that of the front face.

For the conventional representation of the smaller sizes it is sufficient to draw the long diameter of the head twice the diameter of the shaft, and the thickness of both head and nut equal to the diameter of the shaft.

Many different lock-nut devices to prevent nuts from working loose, are used in machine design. The jam nut or check nut is a common method, Fig. 323, using either two "three-quarters" or standard nuts, or one full and one thin nut. Theoretically the thin nut should be under, but it is sometimes placed outside. *D* is another application. In automobile work the "castle" nut shown in Fig. 324 with pin through the bolt is universally used. These are made on the A. L. A. M. (Assn. of Licensed Automobile Manufacturers) standard, which has finer threads and smaller heads and nuts than the U. S. Standard. A table of sizes of A. L. A. M. bolts is given under the figure.

Cap screws differ from bolts in that they are used for fastening two pieces together by passing through a clear hole in one and

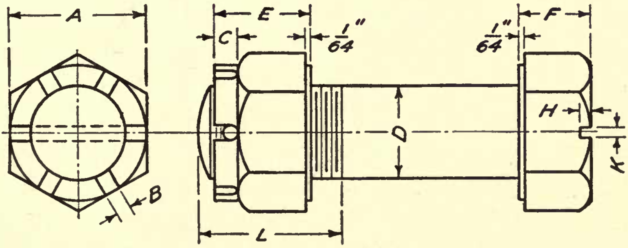


FIG. 324.—A. L. A. M. Standard bolt and castle nut.

D	Threads	A	B	C	E	F	H	K	L
$\frac{1}{4}$	28	$\frac{3}{8}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{9}{32}$	$\frac{3}{16}$	$\frac{3}{32}$	$\frac{1}{16}$	$\frac{3}{8}$
$\frac{5}{16}$	24	$\frac{1}{2}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{21}{64}$	$\frac{15}{64}$	$\frac{7}{64}$	$\frac{1}{16}$	$\frac{15}{32}$
$\frac{3}{8}$	24	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{13}{32}$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{9}{16}$
$\frac{7}{16}$	20	$\frac{11}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{29}{64}$	$\frac{21}{64}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{21}{32}$
$\frac{1}{2}$	20	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{9}{16}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{4}$
$\frac{9}{16}$	18	$\frac{7}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{39}{64}$	$\frac{27}{64}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{27}{32}$
$\frac{5}{8}$	18	$\frac{15}{16}$	$\frac{5}{32}$	$\frac{1}{4}$	$\frac{23}{32}$	$\frac{15}{32}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{15}{16}$
$\frac{11}{16}$	16	1	$\frac{5}{32}$	$\frac{1}{4}$	$\frac{49}{64}$	$\frac{33}{64}$	$\frac{1}{8}$	$\frac{3}{32}$	$1\frac{1}{32}$
$\frac{3}{4}$	16	$1\frac{1}{8}$	$\frac{5}{32}$	$\frac{1}{4}$	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$1\frac{1}{8}$
$\frac{7}{8}$	14	$1\frac{1}{4}$	$\frac{5}{32}$	$\frac{1}{4}$	$\frac{29}{32}$	$\frac{21}{32}$	$\frac{1}{8}$	$\frac{3}{32}$	$1\frac{5}{16}$
1	14	$1\frac{7}{16}$	$\frac{5}{32}$	$\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{32}$	$1\frac{1}{2}$

screwing into a tapped hole in the other. The heads are the same thickness as the diameter of the bolt, but are usually somewhat smaller in diameter than bolt heads. Some cap screw heads are made, however, to U. S. Standard. Fig. 325 shows six different forms with an accompanying table of sizes.

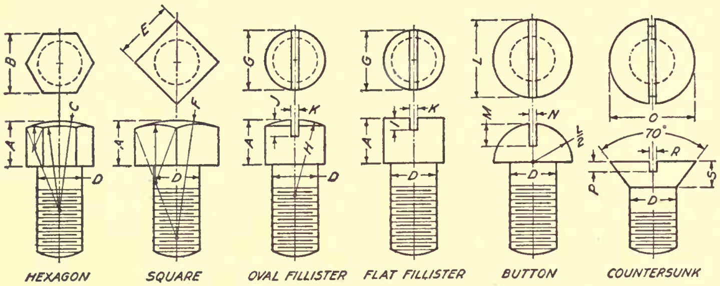


FIG. 325.—Cap screws.

D	A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	R	S
1/8						3/16	15/64	1/16	5/64	.032	7/32	1/16	.035	1/4	3/64	.040	3/32
3/16						1/4	5/16	1/16	3/32	.040	5/16	3/32	.051	3/8	3/64	.064	9/64
1/4	1/4	7/16	21/32	3/8	3/4	3/8	15/32	1/16	3/32	.064	7/16	1/8	.072	15/32	1/16	.072	5/32
5/16	5/16	1/2	3/4	7/16	7/8	7/16	35/64	5/64	1/4	.072	9/16	5/32	.091	5/8	5/64	.102	7/32
3/8	3/8	9/16	27/32	1/2	1	9/16	45/64	3/32	9/64	.091	5/8	3/16	.102	3/4	3/32	.114	17/64
7/16	7/16	5/8	15/16	9/16	1 1/8	5/8	25/32	7/64	11/64	.102	3/4	7/32	.114	13/16	3/32	.114	17/64
1/2	1/2	3/4	1 1/8	5/8	1 1/4	3/4	15/16	1/8	3/16	.114	13/16	1/4	.114	7/8	3/32	.128	17/64
9/16	9/16	13/16	1 7/32	11/16	1 3/8	13/16	1 1/64	9/64	7/32	.114	15/16	9/32	.114	1	7/64	.133	5/16
5/8	5/8	7/8	1 5/16	3/4	1 1/2	7/8	1 3/32	5/32	15/64	.128	1	5/16	.133	1 1/8	1/8	.133	23/64
3/4	3/4	1	1 1/2	7/8	1 3/4	1	1 1/4	3/16	9/32	.133	1 1/4	3/8	.133	1 3/8	5/32	.133	7/16
7/8	7/8	1 1/8	1 11/16	1 1/8	2 1/4	1 1/8	1 13/32	7/32	21/64	.133							
1	1	1 1/4	1 7/8	1 1/4	2 1/2	1 1/4	1 9/16	1/4	3/8	.165							
1 1/8	1 1/8	1 3/8	2 1/16	1 3/8	2 3/4												
1 1/4	1 1/4	1 1/2	2 1/4	1 1/2	3												

Studs.—Threaded studs are bolts having a thread on each end, one end to screw into a tapped hole, the other for a nut, Fig. 326. The screwed end should be 1 1/4 to 1 1/2 D long.

Set screws are used for holding two parts in relative position, being screwed through one part and having the point set against the other. They are made with square and hex. heads, whose thickness and short diameter are equal to the diameter of the

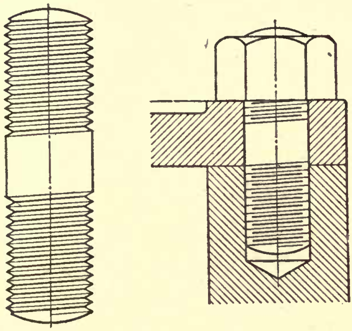


Fig. 326.—Studs.

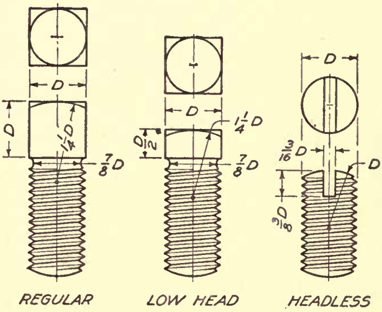


Fig. 327.—Set screws.

screw, with low head, and headless, as shown in Fig. 327; and with points of different shapes for different purposes, Fig. 328. The Allen headless set screw, patented in 1910, with countersunk

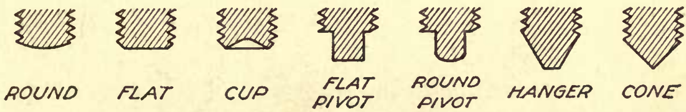


Fig. 328.—Set screw points.

hexagonal socket, shown in Fig. 330, is approved by factory inspectors as safe, and is used where there might be danger of clothing being caught in moving parts.

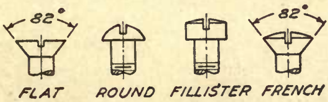


Fig. 329.—Machine screws.

Machine screws are specified by gage number, not by sizes in fractions of an inch. Fig. 329 shows the various forms of machine screw heads.

A new standard for machine screws was proposed in 1907 by the American Society of Mechanical Engineers but has not yet come into general use. Tables of these sizes, as well as for other

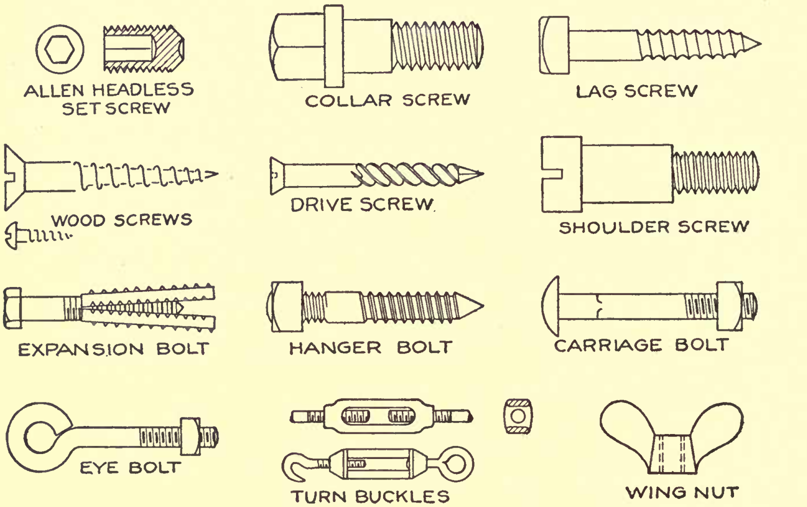


Fig. 330.—Various bolts and screws.

standard screws, may be found in Kent, American Machinist's and other handbooks.

Various other types of bolts and screws are illustrated in Fig. 330.

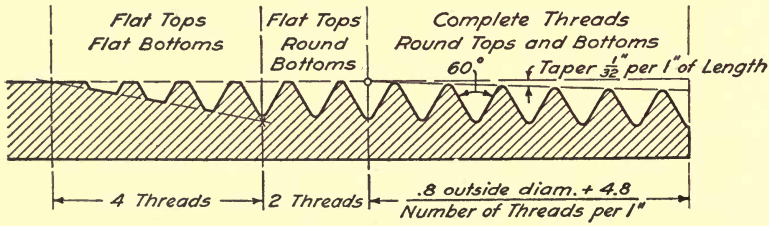


Fig. 331.—Section of Briggs pipe thread.

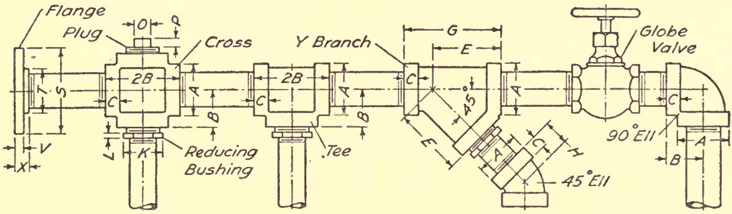
Pipe Threads and Fittings.

Pipe threads are cut on a taper, known as the Briggs Standard, illustrated in enlarged scale in Fig. 331. In drawing pipes the taper of the threaded portion is usually slightly exaggerated.

DIMENSIONS OF STANDARD STEEL AND WROUGHT IRON PIPE.

Nominal inside diameter	Actual outside diameter	Actual inside diameter	Internal area	Thds. per inch	Dist. pipe enters	Actual inside diam.	
						Extra heavy	Double extra
$\frac{1}{8}$	.405	.270	.057	27	$\frac{3}{16}$	.205	
$\frac{1}{4}$	.540	.364	.104	18	$\frac{9}{32}$	.294	
$\frac{3}{8}$	.675	.494	.191	18	$\frac{19}{64}$	.421	
$\frac{1}{2}$	.840	.623	.304	14	$\frac{3}{8}$	.542	.244
$\frac{3}{4}$	1.05	.824	533	14	$\frac{13}{32}$	.736	.422
1	1.315	1.048	.861	$11\frac{1}{2}$	$\frac{1}{2}$	.951	.587
$1\frac{1}{4}$	1.66	1.38	1.496	$11\frac{1}{2}$	$\frac{35}{64}$	1.272	.885
$1\frac{1}{2}$	1.9	1.61	2.036	$11\frac{1}{2}$	$\frac{9}{16}$	1.494	1.088
2	2.375	2.067	3.356	$11\frac{1}{2}$	$\frac{37}{64}$	1.933	1.491
$2\frac{1}{2}$	2.875	2.468	4.78	8	$\frac{7}{8}$	2.315	1.755
3	3.5	3.067	7.383	8	$\frac{15}{16}$	2.892	2.284
$3\frac{1}{2}$	4	3.548	9.887	8	1	3.358	2.716
4	4.5	4.026	12.73	8	$1\frac{1}{16}$	3.818	3.136
$4\frac{1}{2}$	5	4.508	15.961	8	$1\frac{7}{64}$	4.28	3.564
5	5.563	5.045	19.986	8	$1\frac{5}{32}$	4.813	4.063
6	6.625	6.065	28.89	8	$1\frac{1}{4}$	5.751	4.875
7	7.625	7.023	38.738	8	$1\frac{3}{8}$	6.625	5.875
8	8.625	7.982	50.027	8	$1\frac{7}{16}$	7.625	6.875
9	9.625	8.937	62.72	8	$1\frac{9}{16}$	8.625	
10	10.75	10.019	78.823	8	$1\frac{11}{16}$	9.75	

Pipe is designated by the nominal inside diameter, which differs slightly from the actual inside diameter, as will be noted from the table on page 169. "Extra" and "double extra" heavy pipe has the same outside diameter as standard weight pipe of the same nominal size, the added thickness being on the inside. Thus the outside diameter of 1″ pipe is 1.315, the inside diameter



SIZE OF PIPE	A	B	C	E	G	H	K	L	O	P	S	T	V	X
1/8	31/32	3/4	5/16	1 3/16	1 13/16	21/32			1/4	1/4				
1/4	1 1/8	29/32	13/32	1 7/16	2 7/32	25/32			3/8	1/4				
3/8	1 3/8	1 1/16	1/2	1 11/16	2 19/32	29/32	13/16	1/4	3/8	5/16				
1/2	1 5/8	1 1/4	9/16	2 1/32	3 1/16	1 1/32	1 3/32	1/4	3/8	5/16				
3/4	1 15/16	1 7/16	21/32	2 13/32	3 21/32	1 3/16	1 9/32	1/4	7/16	3/8	3 1/2	1 1/2	7/16	5/8
1	2 5/16	1 11/16	3/4	2 29/32	4 9/32	1 3/8	1 21/32	3/8	11/16	7/16	4	1 15/16	7/16	11/16
1 1/4	2 3/4	2	27/32	3 1/2	5 3/32	1 19/32	2	3/8	3/4	1/2	4 1/2	2 5/16	1/2	3/4
1 1/2	3 1/8	2 3/16	29/32	3 29/32	5 19/32	1 11/16	2 5/32	3/8	13/16	1/2	5	2 5/8	9/16	7/8
2	3 11/16	2 19/32	1 1/32	4 3/4	6 3/4	2	2 3/4	3/8	1 1/16	9/16	6	3 1/8	5/8	1
2 1/2	4 5/16	2 31/32	1 5/32	5 9/16	7 13/16	2 1/4	3 15/32	7/16	1 3/16	5/8	7	3 5/8	11/16	1 1/16
3	5 1/32	3 11/32	1 1/4	6 15/32	8 15/16	2 15/32	4 1/32	1/2	1 5/16	5/8	7 1/2	4 5/16	3/4	1 1/8
3 1/2	5 23/32	3 3/4	1 3/8	7 5/16	10 1/16	2 3/4	5 3/16	1/2	1 1/2	3/4	8 1/2	4 7/8	13/16	1 3/16
4	6 3/8	4 1/8	1 1/2	8 5/16	11 5/16	3	5 29/32	1/2	1 3/4	3/4	9	5 3/8	15/16	1 1/4
4 1/2	7 1/32	4 1/2	1 19/32	8 15/16	12 3/16	3 1/4	6 1/32	9/16	2	13/16	9 1/4	5 13/16	15/16	1 5/16
5	7 3/4	4 27/32	1 11/16	9 3/4	12 5/8	3 15/32	7 3/16	9/16	2 1/4	13/16	10	6 7/16	15/16	1 7/16
6	9	5 17/32	1 13/32	11 5/16	15 7/32	3 29/32	8 5/8	3/4	2 1/2	1	11	7 9/16	1	1 1/2

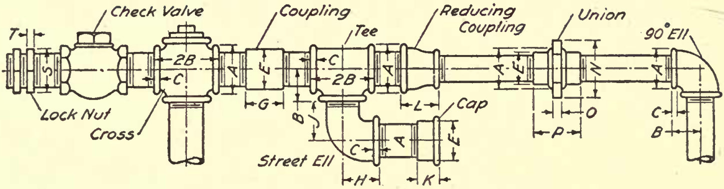
FIG. 332.—Cast iron fittings.

of standard 1″ pipe 1.05, of 1″ extra strong .951, and of XX, .587″.

The dimensions of fittings vary somewhat with the different manufacturers. In dimensioning piping the best practice is to give figures from center to center of fittings.

Fig. 332 illustrates some of the ordinary cast iron fittings. The dimensions indicated are given in the accompanying table.

Fig. 333 shows malleable fittings.



SIZE OF PIPE	A	B	C	E	G	H	J	K	L	N	O	P	S	T
1/8	5/8	5/8	1/8	19/32	15/16			3/8		1 5/32	3/8	1 1/4		
1/4	7/8	3/4	3/16	3/4	1 1/32	1	1	5/8		1 5/32	1/2	1 1/4	7/8	1/4
3/8	1 3/16	1	1/4	29/32	1 5/32	1	1 5/32	5/8		1 7/16	1/2	1 5/8	1	5/16
1/2	1 3/8	1 1/16	1/4	1 3/32	1 5/16	1 1/16	1 5/16	7/8		1 13/16	1/2	1 7/8	1 1/4	3/8
3/4	1 3/4	1 1/4	1/4	1 11/32	1 9/16	1 5/16	1 7/8	7/8	1 9/16	2 5/32	1/2	2 1/4	1 1/2	3/8
1	2 1/16	1 3/8	1/4	1 5/8	1 13/16	1 5/8	2	1 1/16	1 7/8	2 19/32	9/16	2 3/8	1 7/8	7/16
1 1/4	2 1/2	1 3/4	3/8	1 31/32	2 1/16	1 7/8	2	1 1/4	2 3/16	3 1/32	9/16	2 5/8	2 1/8	1/2
1 1/2	2 3/4	2	3/8	2 1/4	2 5/16	2	2	1 3/8	2 3/8	3 3/8	5/8	2 7/8	2 3/8	1/2
2	3 3/8	2 1/4	3/8	2 23/32	2 9/16	2 1/2	2 7/16	1 1/2	2 5/8	4 1/32	5/8	3 1/4	3	1/2
2 1/2	4	2 3/4	7/16	3 5/16	2 7/8			1 5/8	3 1/4	5 1/32	3/4	3 1/2	4 1/8	5/8
3	5	3	1/2	3 15/16	3 1/16			1 7/8		5 5/8	7/8	3 3/4	4 1/2	3/4
3 1/2	5 3/8	3 1/2	5/8	4 7/16	3 7/16			2		6 5/8	7/8	4 3/4	5	1
4	6 1/4	4	5/8	4 15/16	3 7/16			2		7 7/32	7/8	4 3/4	6 3/4	1
4 1/2	6 1/2	4 1/2	5/8	5 17/32	3 5/8			2 1/4					7	1
5	7 1/8	5	5/8	6 1/4	4 1/8			2 3/8					7 1/2	1
6	8 1/8	6	5/8	7 9/32	4 1/8			2 1/2					8 1/4	1

FIG. 333.—Malleable fittings.

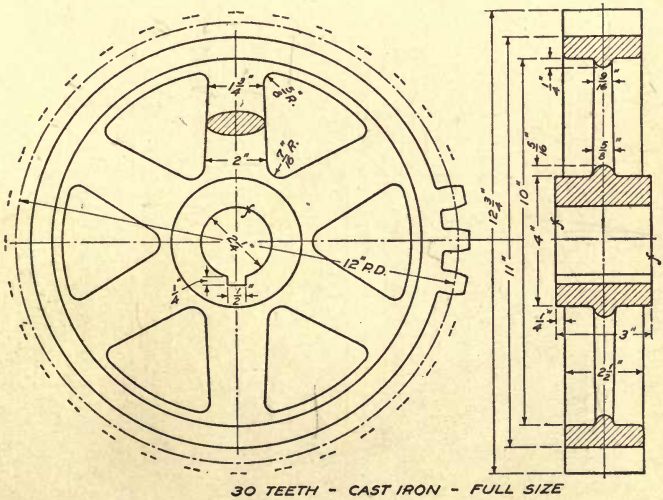


FIG. 334.—Cast spur gear.

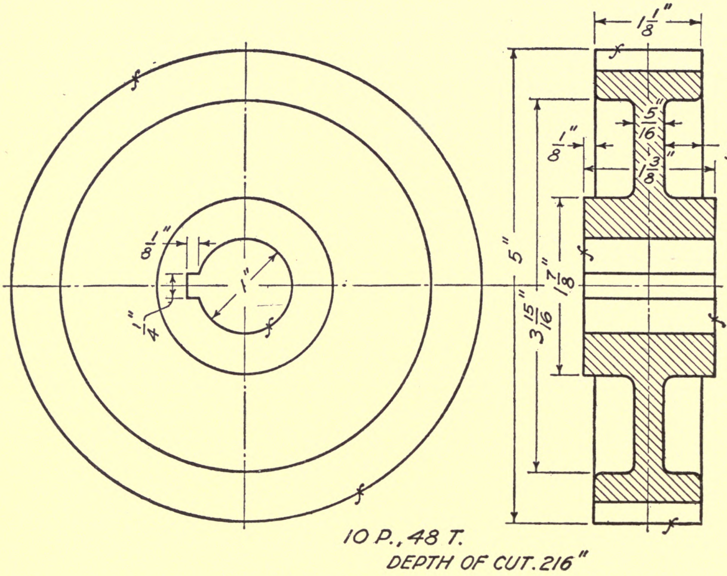


Fig. 335.—Cut spur gear.

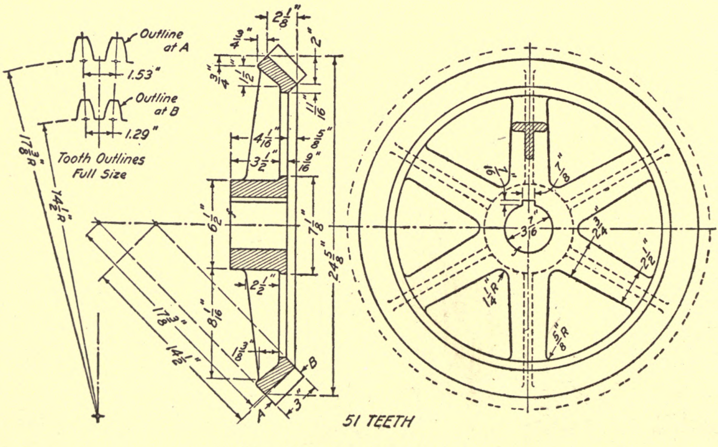


Fig. 336.—Cast bevel gear.

Gears.

While it is not within our scope to take up any machine design, it is important that designers know the correct methods for the representation of designed parts. In the working drawings of

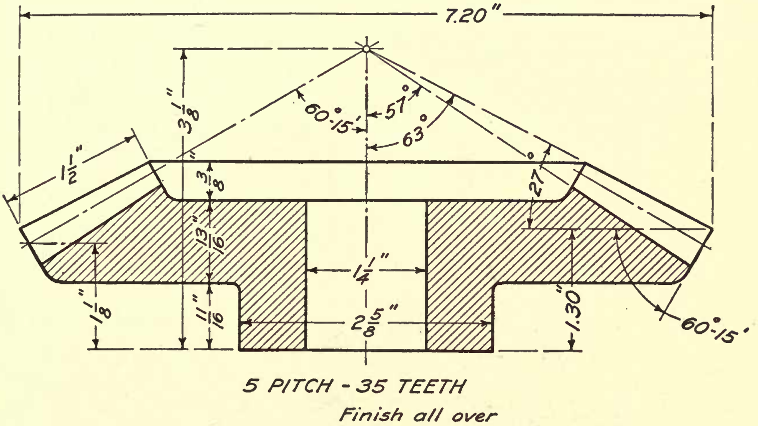


FIG. 337—Cut bevel gear.

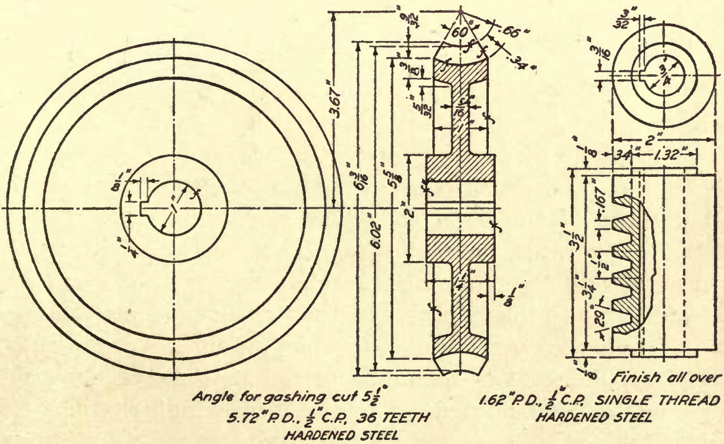


FIG. 338.—Worm and gear.

gears and toothed wheels the teeth are never drawn on the wheel. For **cast gears** the pitch circle, addendum circle and root circle are drawn, and the full sized outline of one tooth, Fig. 334.

For **cut gears** the blank is drawn, and notes added for full information regarding pitch, cutters, etc., Fig. 335.

Fig. 336 is a drawing of a cast bevel gear, showing the method of complete dimensioning for the construction of the pattern. Fig. 337 is a cut bevel gear and Fig. 338 is a worm gear.

On assembly drawings gears are represented as in Fig. 339.

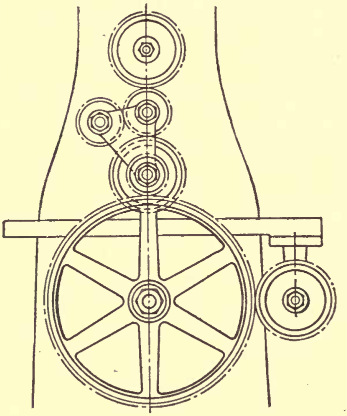


FIG. 339.

CONVENTIONAL SYMBOLS.

The methods of drawing screw-threads and gears just considered would be called conventional, as they do not represent real outlines of the objects. Other conventions are used for electrical apparatus, for materials, etc.

In specifying the materials of which objects are to be made, the safest rule to follow is to add the name of the material as a note. There are cases however in which when the piece is shown in section, adjacent parts made of different materials can be indicated to good advantage by using different characters of cross-hatching.

The commonest example of this is in distinguishing a bearing or lining metal poured into place hot, such as babbitt metal. It is universal practice to show such metals by the conventional symbol of crossed lines shown in Fig. 340. An example of this is the lead lined valve, Fig. 144.

The quickest way to make this symbol is to section over both the lining metal and the adjacent cast iron at once, then cross the lining metal in the other direction.

There have been a number of different codes of symbols proposed and published for the representation on working drawings of different metals and materials. Aside from their doubtful value on account of the lack of agreement, they are all open to the same objection, that of the added time necessary for their execution.

With the variety of materials used in modern construction it is entirely impracticable to have symbols for all.

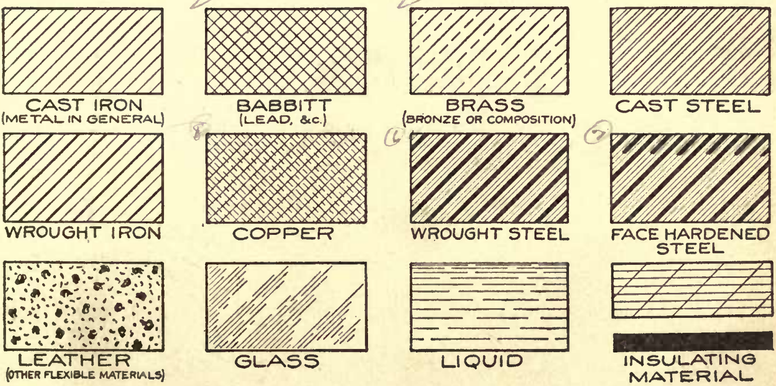


Fig. 340.—Symbols for materials in section.

Fig. 340 gives conventions for a number of different materials. Those in the first line are accepted by practically all who use conventional cross-hatching. There is much variation in the symbols proposed for the other materials shown. Those given are part of the codes of government standards of the Bureau of Steam Engineering and the Bureau of Construction U. S. N., who require their use on assembly drawings submitted by firms estimating on government work.

Until a standard is adopted universally it would seem necessary to add to a drawing made with symbolical section lining, a key to materials, as is done in architectural drawing, or else to letter the name of the material on each piece, in which case the fancy section-lining would appear to be unnecessary.

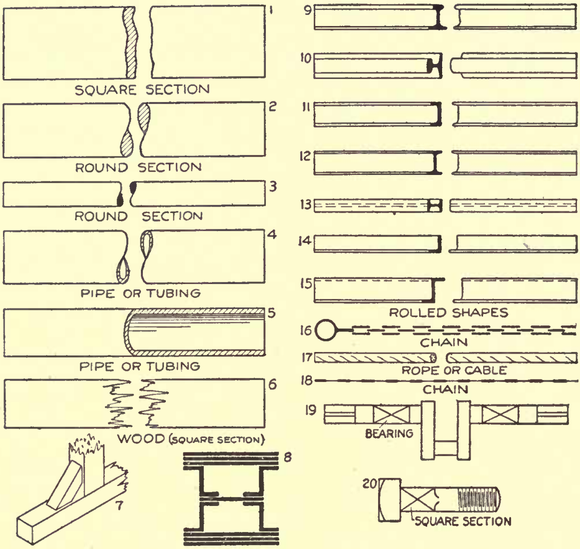


FIG. 341.—Conventional breaks and other symbols.

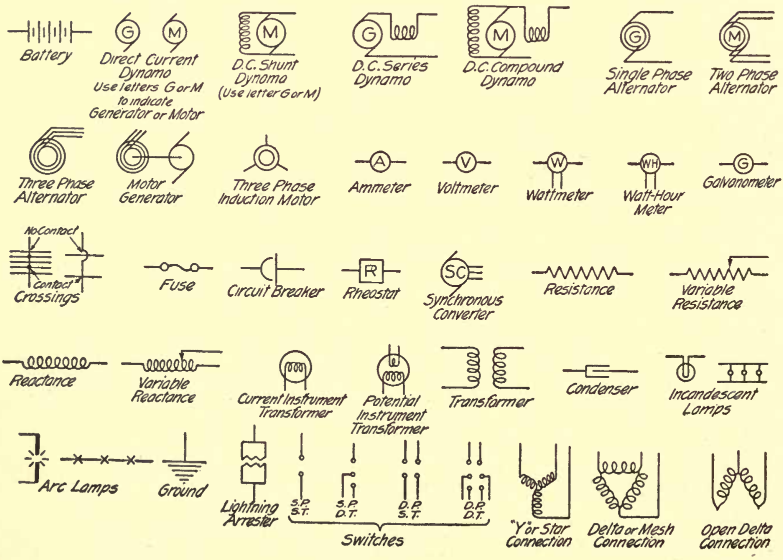


FIG. 342.

Fig. 341 shows a number of conventional breaks and other useful symbols.

In making a detail of a long bar of uniform section there is evidently no necessity for drawing its whole length. It may be shown much better by breaking out a piece and giving the length in a dimension.

The crossed diagonals are used for two distinct purposes, to indicate position or finish for a bearing, and to indicate a piece square in section, but are not apt to be confused.

Sheet metal and structural shapes in section to small scale may be shown most effectively in solid black with white spaces between parts.

Very short section-lines are best made freehand.

Fig. 342 gives a set of electrical diagrammatic symbols. There is no universal standard, but of those proposed here a number are in general use. The standard wiring symbols of the National Electrical Contractors Association is given on page 221.

COMMERCIAL SIZES.

The following notes give the commercial methods of specifying sizes of the items in the list. The material must, of course, always be specified.

Chain.—Give diameter of rod used.

Electrical Conduit.—Same as pipe.

Pipe.—Give nominal inside diameter.

R. R. Rails.—Give height of section and weight per yard.

Rolled Steel Shapes.—Give name, essential dimensions and weight per foot.

Rope.—Give largest diameter.

Shafting.—The best practice is to give the actual diameter.

Sheet Metal.—Give thickness by gage number, or in thousandths of an inch (for 3/16″ and over, give thickness in fractions).

Springs.—Helical, give outside diameter, gage of wire, and coils per inch when free.

Tapered Pieces.—Give size at small end, and taper per foot.

Tubing.—Give outside diameter and thickness.

Wire.—Give diameter by gage number or in thousandths of an inch.

Wire Cloth.—Give number of meshes per lineal inch, and gage of wire.

Wood Screws.—Give length, diameter by number, and kind of head.

Special.—Manufactured articles or fittings, give manufacturer's name and catalogue number.

CHECKING.

Before being sent to the shop, a working drawing must be checked for errors and omissions by an experienced checker, who in signing his name to it becomes responsible for any inaccuracy. This is the final "proof-reading" and cannot be done by the one who has made the drawing nearly so well as by another person. In small offices all the work is checked by the chief draftsman, and draftsmen sometimes check each other's work; in large drafting rooms one or more checkers who devote all their time to this kind of work are employed.

Students may gain experience in this work by being assigned to check other students' work.

To be effective, checking must be done in an absolutely systematic way, and with thorough concentration.

Professor Follows in his "Dictionary of Mechanical Drawing" has specified admirably the work of checking, in twelve items, which are given with his permission. Each of these should be followed through separately, allowing nothing to distract the attention from it. As each dimension or feature is verified a checkmark should be placed above it.

1. Put yourself in the position of those who are to read the drawing and find out if it is easy to read and tells a straight story. Always do this before checking any individual features; in other words, before you have had time to become accustomed to the contents.
2. See that each piece is correctly illustrated and that all necessary views are shown, but none that are not necessary.
3. Check all the dimensions by scaling, and, where advisable, by calculation also.
4. See that dimensions for the shop are given as required by the shop, that is, that the shop is not left to do any adding or subtracting in order to get a needed dimension.

5. Go over each piece and see that finishes are properly specified.
6. See that every specification of material is correct and that all necessary ones are given.
7. Look out for "interferences." This means check each detail with the parts that will be adjacent to it in the assembled machine and see that proper clearances have been allowed.
8. When checking for clearances in connection with a mechanical movement, lay out the movement to scale, figure the principal angles of motion and see that proper clearances are maintained in all positions.
9. See that all the small details, as screws, bolts, pins, keys, rivets, etc., are standard and that, where possible, stock sizes have been used.
10. Check every feature of the record strip.
11. Review the drawing in its entirety in connection with any points that have suggested themselves during the above checking.
12. Bearing in mind the value of explanatory notes, do not fail to add such notes as your experience tells you will increase the efficiency of the drawing.

STRUCTURAL DRAWING.

The term "structural drawing" is always understood to mean working drawings and details for steel construction, such as bridges, roof trusses, skeletons of tall buildings, etc.

Structural work differs from machine work in that it is made up of rolled shapes and put together permanently with rivets. The function of the drawing is to show the shapes and sizes of the steel used in the design, and the spacing of the rivets.

Some of the parts are put together in the shop and some at the place of erection, and a distinction must be shown between "shop rivets" and "field rivets." The holes left for field connection are always made solid black.

Fig. 343 shows the Osborn symbols for riveting, which are so universally used that no key on the drawing is necessary; and Fig. 344 shows rivets in larger scale.

In drawing rivets the drop pen, Fig. 30, is a favorite instrument with structural draftsmen.

The general rules for working drawings are of course applicable to this branch, but there are some minor differences in common practice that should be noticed.

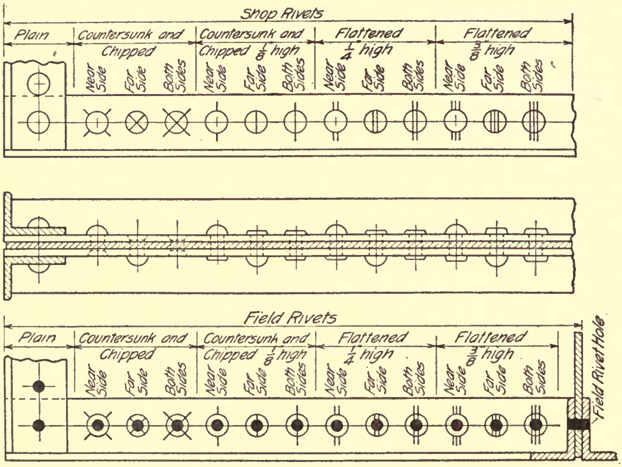


FIG. 343.—Standard symbols for riveting.

Structural drawings are necessarily made with finer outlines than machine drawings, and shade lines are never used.

To prevent confusion on the tracing, center lines and gage lines are very often drawn in red.

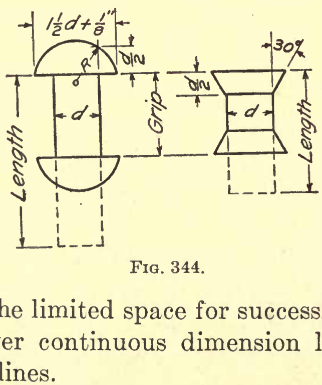


FIG. 344.

On account of the limited space for successive dimensions, the figures are set over continuous dimension lines, instead of in spaces left in the lines.

Dimensions over one foot are given in feet and inches.

Care should be taken that dimensions are given to commercial sizes of materials.

Angles, as for gussets, are indicated by their tangent, on a 12″ base line.

The stress diagram is often added to the drawing.

Bent plates should be developed, and the "stretchout" length of bent forged bars given.

When showing only part of a given piece, always draw it from the left end toward the right.

A bill of material always accompanies a structural drawing. This may be put on the drawing, but the best practice now attaches it as a separate "bill sheet."

Figs. 345 and 346 are given to illustrate the general make-up of structural drawings. The original drawings were 24″x36″. When a view is given under a front view, as in Fig. 345, it is not a bottom view, but a section taken through the web, above the lower flange.

PROBLEMS.

The first part of any working drawing problem consists of the selection of views, the choice of suitable scales, and the arrangement of the sheet. In class work the preliminary sketch layout should be submitted for approval before the drawing is commenced.

All views of an object must be drawn to the same scale, but different objects on the same sheet may be drawn to different scales.

The problems here given may be drawn on 12″x18″ or 18″x24″ sheets. Their division into groups is suggestive rather than arbitrary, and the selections made from them will depend upon the kind and length of course.

Group I.—Bolts, Screws, Pipes, etc.

Prob. 1.—Draw helical screw threads and springs as indicated in Fig. 347.

Prob. 2.—Draw a bolt sheet containing: 3/4″x3″ bolt with hex. head and nut; 3/4″x3″ square head bolt; 7/8″ x3 1/2″ stud, with hex. nut; 1/2″x2″ hex. head cap screw; 5/8″x1 1/2″ cup point set screw;

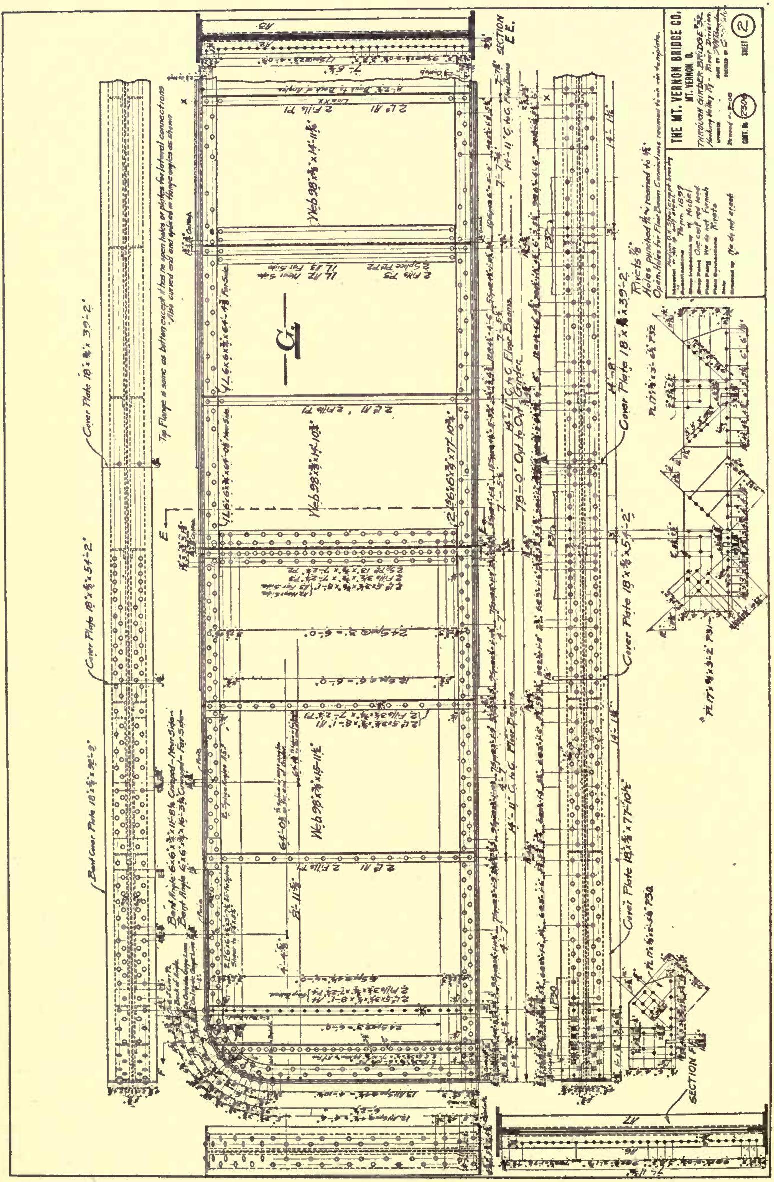


FIG. 345.—Plate girder.

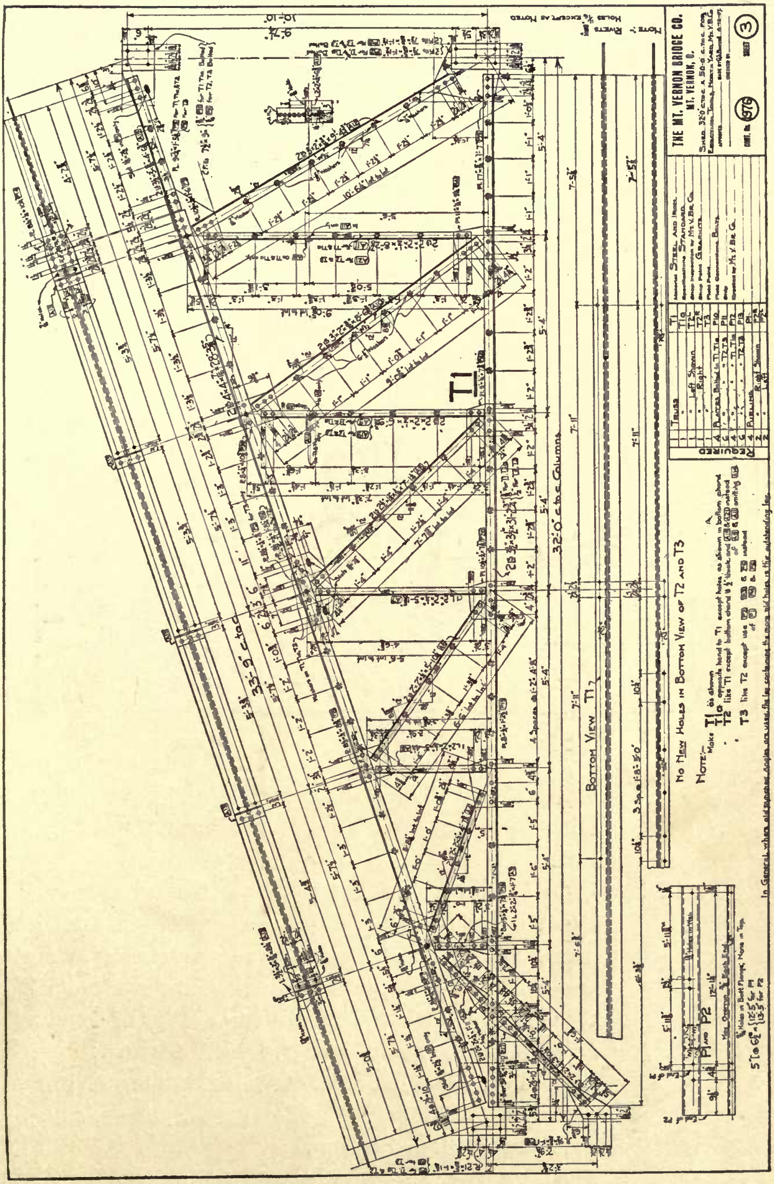


Fig. 346.—Roof truss.

Prob. 2.—1/4″x1 1/2″ oval fillister head machine screw; (Continued.) 5/8″x3 1/4″ A. L. A. M. bolt and castle nut; 1/2″x2 1/2″ low head, round point set screw, with jam nut; 5/16″x3/4″ headless set screw, with hanger point; 3/8″x1 1/2″ countersunk head cap screw; 1/4″x1 3/4″ round head machine screw; 3 1/2″ lag screw (1/2″ diam.); 2 1/2″ flat head

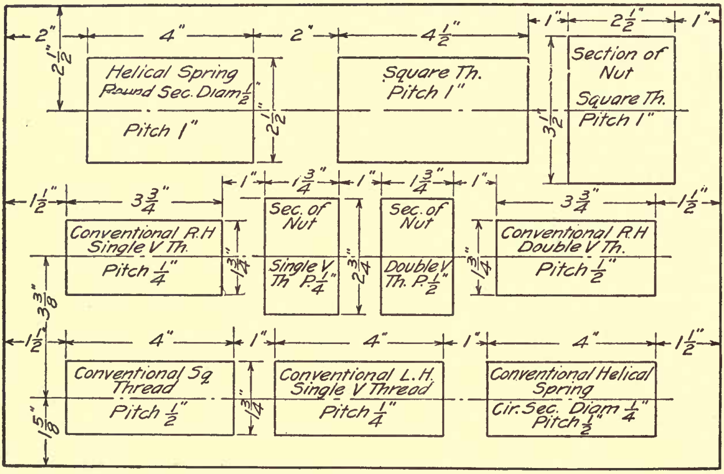


FIG. 347.

wood screw (3/16″ diam.); 1/2″x4″ hanger bolt, with lock nut; 5/8″ Allen set screw; 1/4″ wing nut.

Prob. 3.—Pipe Fittings. In the upper left-hand corner of sheet draw a 2″ T. Plug one outlet, in another place a 1 1/2″x2″ bushing, in remaining outlet use a 2″ close nipple and on it screw a 1 1/2″x2″ reducing bushing. Lay out remainder of sheet so as to include the following 1 1/2″ fittings: coupling, globe valve, R. & L. coupling, angle valve, 45-degree ell, 90-degree ell, 45-degree Y, cross, cap, 3 part union, flange union.

Add extra pipe, nipples and fittings so that the system will close at the reducing fitting first drawn.

Prob. 4.—A Piping Problem. Given two sources of pressure supply—a city main and a steam pump. A sprinkler system must have pressure on at all times, and is to be connected so as to have city pressure, pump pressure, or pressure from an overhead tank. A battery of boilers is also to be connected to these three sources. The tank is to be capable of supply from either pump or main.

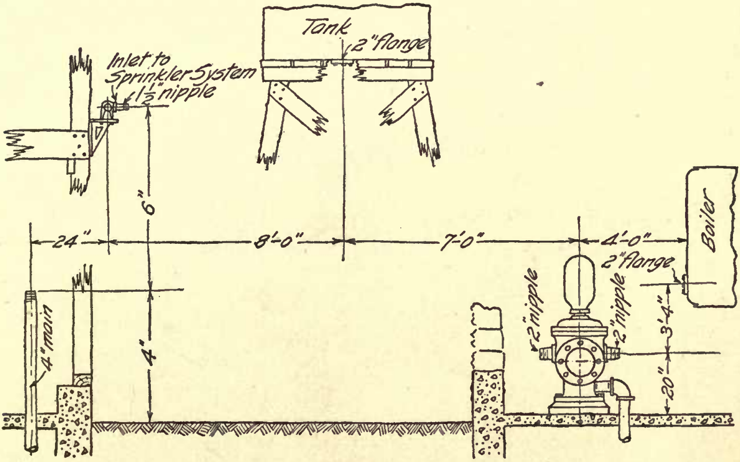


FIG. 348.

Design a pipe layout in elevation, so that each system can be operated independently, and be perfectly interchangeable, using the fewest fittings and simplest connections. Fig. 348 is a sketch showing the position of the outlets.

Group II.—Study Sheets in Dimensioning.

(All to be in orthographic projection, with necessary views.)

Prob. 1.—Make a freehand working sketch of the casting, Fig. 349, showing the location of all dimensions, according to the rules for dimensioning, thus ←———x———→

Prob. 2.—Same for Fig. 350.

Prob. 3.—Freehand sketch of yoke (*A*) Fig. 351, indicating dimensions for the blacksmith. The holes to be punched.

Prob. 4.—Same for equalizing bar (*B*) Fig. 351.

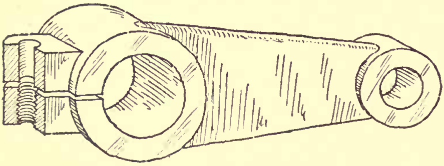


Fig. 349.

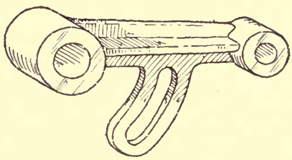


Fig. 350.

Prob. 5.—Freehand sketch of casting, Fig. 352, giving necessary *machine shop* dimensions in blank.

Prob. 6.—Same for Fig. 353.

Additional practice may be had by applying the rules for dimensioning to Figs. 130, 140, 294, 295, 296, etc.

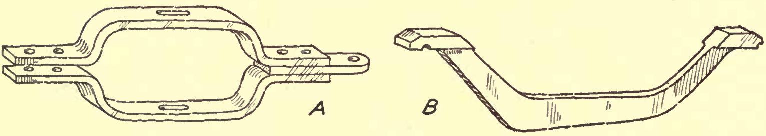


Fig. 351.

Group III.—Drawing from Sketches.

Models, furnished by the Department, are to be sketched and measured; drawings are to be made from the sketches

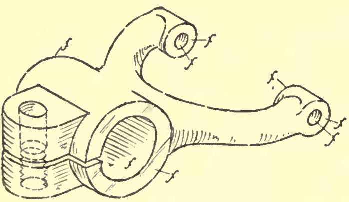


Fig. 352.

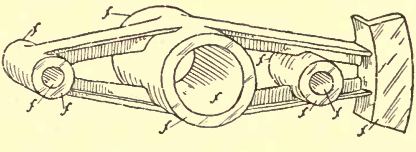


Fig. 353.

without further reference to the model or machine; sketches to be submitted along with finished tracings.

Reference, Chapter X, Technical Sketching.

Group IV.—Machine Parts, etc.

Prob. 1.—Make working drawing of crank shaft from dimensioned sketch, Fig. 354.

Prob. 2.—Working drawing of cross-head, Fig. 355. (Notice the occurrence of a curve of intersection.)

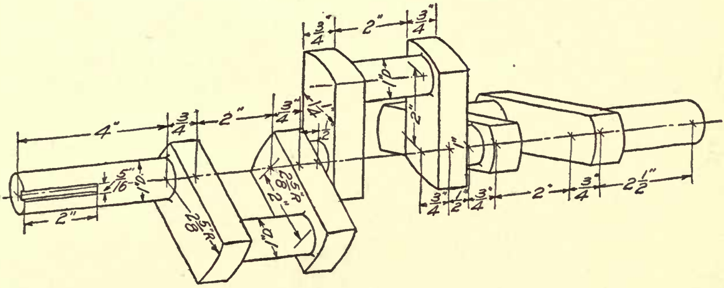


Fig. 354.

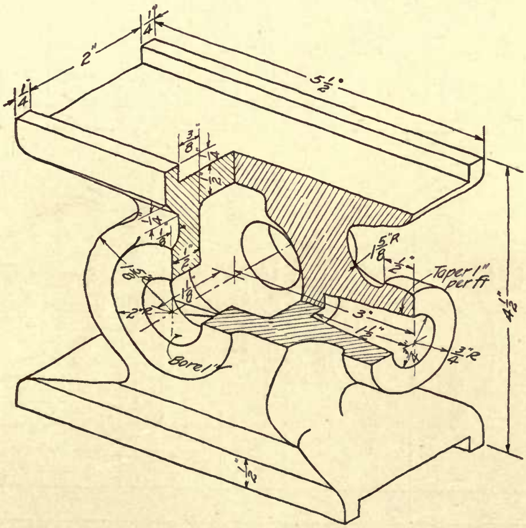
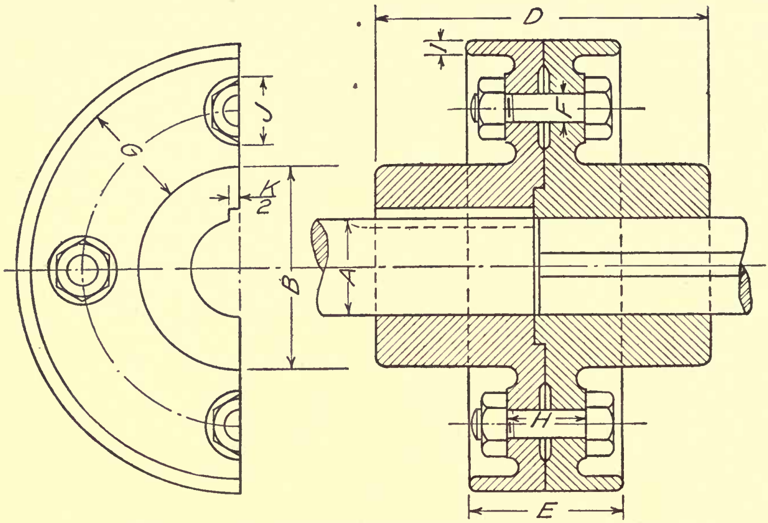


Fig. 355.

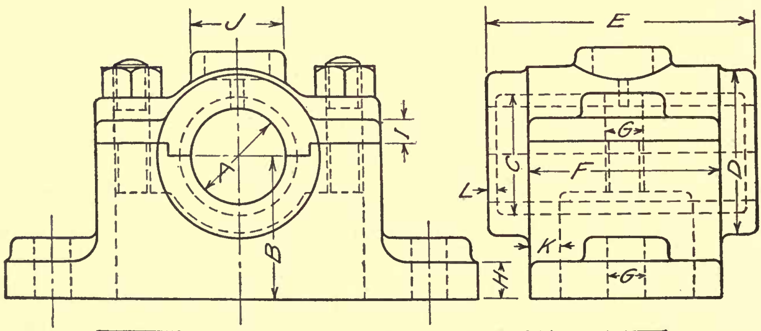
Prob. 3.—Working drawing of a flange coupling, size to be assigned, and dimensions taken from the table accompanying Fig. 356.

Prob. 4.—Working drawing of bearing, from Fig. 357.



A	B	C	D	E	F	G	H	I	J	K
$1\frac{1}{2}$	$3\frac{1}{2}$	1	6	$2\frac{1}{2}$	$\frac{1}{2}$	2	$1\frac{3}{8}$	$\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{8}$
$1\frac{3}{4}$	$3\frac{3}{4}$	$1\frac{1}{8}$	$6\frac{1}{2}$	3	$\frac{5}{8}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{5}{16}$	$1\frac{1}{2}$	$\frac{3}{8}$
2	$4\frac{1}{4}$	$1\frac{1}{4}$	7	$3\frac{1}{4}$	$\frac{5}{8}$	$2\frac{1}{4}$	$1\frac{5}{8}$	$\frac{5}{16}$	$1\frac{1}{2}$	$\frac{1}{2}$
$2\frac{1}{4}$	$4\frac{3}{4}$	$1\frac{3}{8}$	$7\frac{1}{2}$	$3\frac{1}{2}$	$\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{3}{4}$	$\frac{5}{16}$	$1\frac{3}{4}$	$\frac{5}{8}$
$2\frac{1}{2}$	$5\frac{1}{4}$	$1\frac{1}{2}$	8	$3\frac{3}{4}$	$\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{7}{8}$	$\frac{3}{8}$	$1\frac{3}{4}$	$\frac{5}{8}$
$2\frac{3}{4}$	$5\frac{3}{4}$	$1\frac{5}{8}$	9	4	$\frac{7}{8}$	$2\frac{3}{4}$	2	$\frac{3}{8}$	2	$\frac{5}{8}$

FIG. 356.



A	B	C	D	E	F	G	H	I	J	K	L
$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{15}{16}$	$2\frac{5}{8}$	$4\frac{1}{2}$	$2\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{16}$
$1\frac{3}{4}$	2	$2\frac{3}{16}$	3	$5\frac{1}{4}$	$3\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{16}$
2	$2\frac{1}{4}$	$2\frac{7}{16}$	3	6	$3\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{9}{16}$	$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{16}$
$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{11}{16}$	$3\frac{1}{2}$	$6\frac{3}{4}$	$3\frac{3}{4}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{4}$
$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{3}{4}$	$7\frac{1}{2}$	4	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	2	$\frac{5}{8}$	$\frac{1}{4}$
$2\frac{3}{4}$	3	$3\frac{1}{4}$	4	8	5	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	2	$\frac{3}{4}$	$\frac{1}{4}$

FIG. 357.

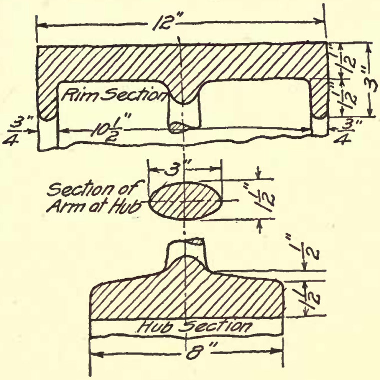
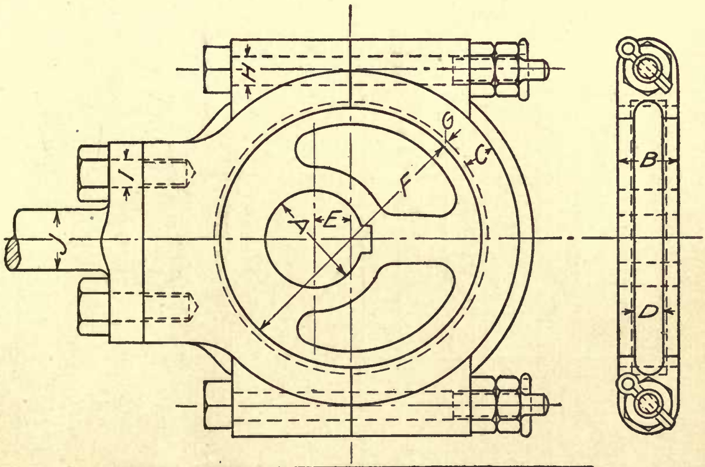


FIG. 358.



A	B	C	D	E	F	G	H	I	J
1¼	⅝	5/16	¼	⅜	3	1/16	5/16	5/16	½
1½	¾	⅜	¼	⅜	3¼	1/16	5/16	5/16	⅝
1¾	¾	⅜	5/16	⅜	3½	1/16	⅜	⅜	⅝
2	¾	⅜	5/16	½	4	1/16	⅜	⅜	⅝
2¼	⅞	7/16	5/16	½	4½	3/32	7/16	7/16	11/16
2½	1	½	⅜	½	4¾	3/32	½	½	¾

FIG. 359.

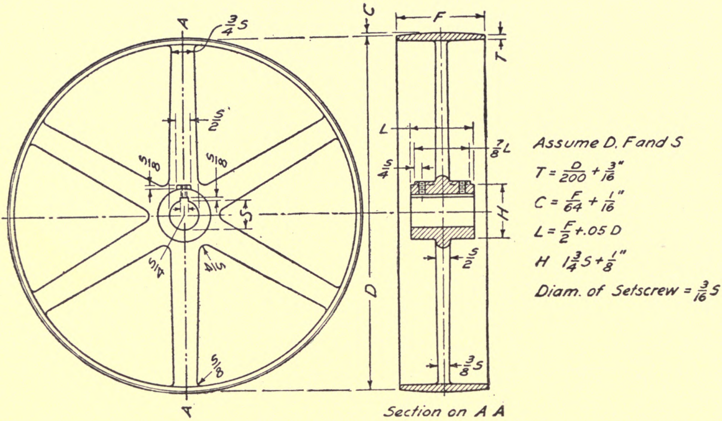
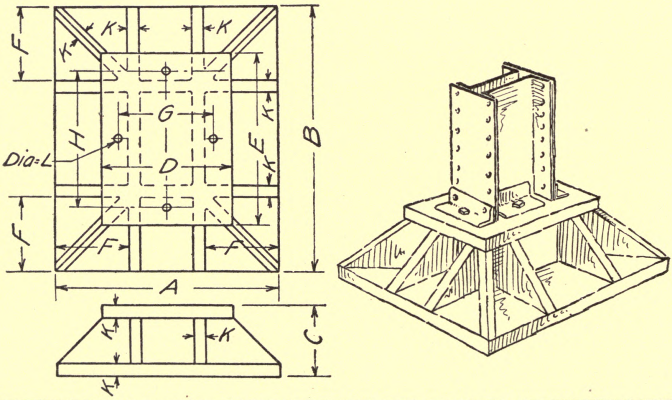


FIG. 360.



Column Section	A	B	C	D	E	F	G	H	K	L
2-8" ⊏s 2-$\frac{1}{4}$"x12" Pl.	19"	22"	6"	11"	14"	6$\frac{1}{4}$"	8"	11"	1"	$\frac{11}{16}$"
2-10" ⊏s 2-$\frac{1}{4}$x13"	22"	26"	7"	13"	17"	7	9$\frac{3}{4}$"	14"	1$\frac{1}{8}$"	$\frac{11}{16}$"
2-12" ⊏s 2-$\frac{5}{8}$"x15"	24"	28"	7"	15"	19"	6$\frac{3}{4}$	12"	16"	1$\frac{1}{4}$"	$\frac{13}{16}$"
2-15" ⊏s 2-$\frac{5}{8}$"x16"	28"	33"	8"	18"	23"	8$\frac{3}{4}$"	15"	20"	1$\frac{1}{2}$"	$\frac{13}{16}$"

FIG. 361.

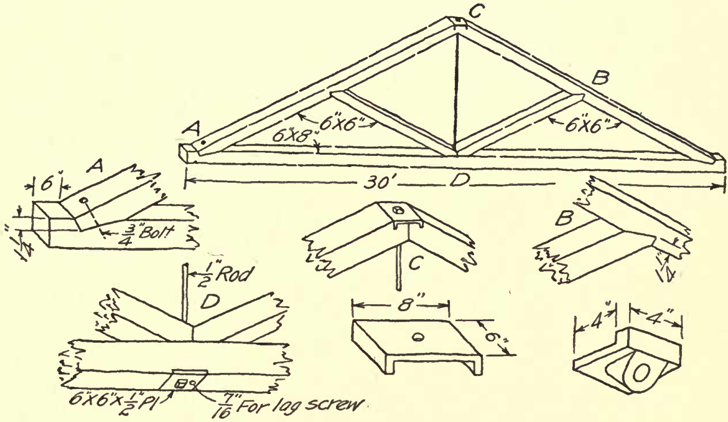


Fig. 362.

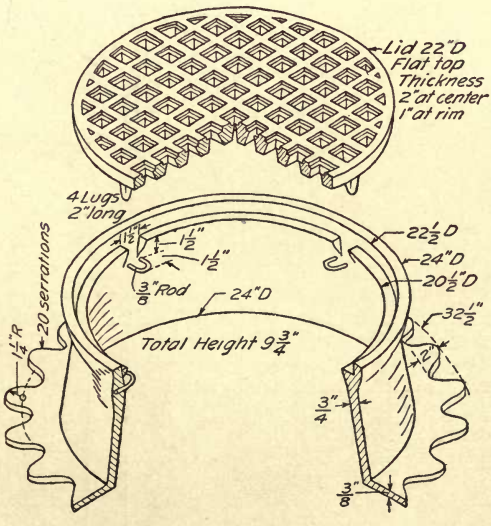


Fig. 363.

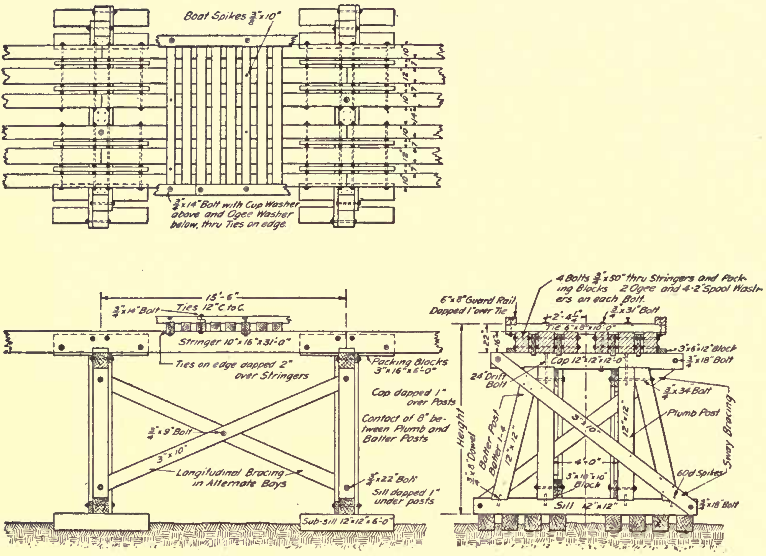
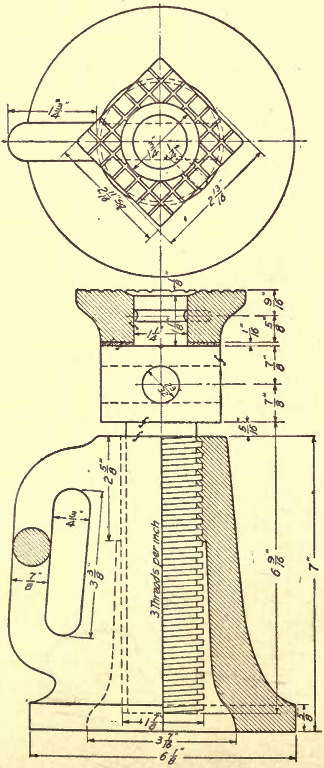

Boat Spikes 3/8"x10"
3/4"x14" Bolt with Cup Washer above and Ogee Washer below, thru Ties on edge.
15'-6"
3/4"x14" Bolt
Ties 12" C to C.
Stringer 10"x16"x31'-0"
Ties on edge dapped 2" over Stringers
Packing Blocks 3"x16"x6'-0"
Cap dapped 1" over Posts
Contact of 8" between Plumb and Batter Posts
3/4"x9" Bolt
3"x10"
Longitudinal Bracing in Alternate Bays
3/4"x22" Bolt
Sill dapped 1" under posts
Sub-sill 12"x12"x6'-0"
4 Bolts 3/4"x50" thru Stringers and Packing Blocks 2 Ogee and 4-2" Spool Washers on each Bolt.
6"x8" Guard Rail Dapped 1" over Tie
3/4"x31" Bolt
Tie 6"x8"x10'-0"
3"x6"x12" Block
3/4"x18" Bolt
Cap 12"x12"x12'-0"
24" Drift Bolt
3/4"x34" Bolt
Plumb Post
Sway Bracing
Height
Batter Post
12"x12"
60d Spikes
Block
Sill 12"x12"
3/4"x18" Bolt

Fig. 364.


3 Threads per inch
7"
6 9/16"
3 7/16"
6 1/8"

Prob. 5.—Working drawing of fly-wheel. Outside diameter 60″; hub 6″ diameter, bore 3″, keyway 1/2″x7/8″. Arms at rim to be 3/4 the size at the hub. Sections of rim, arm, and hub are shown in the sketch, Fig. 358.

Prob. 6.—Working drawing of eccentric, from Fig. 359.

Prob. 7.—Working drawing of pulley, figuring dimensions from formulæ given, Fig. 360.

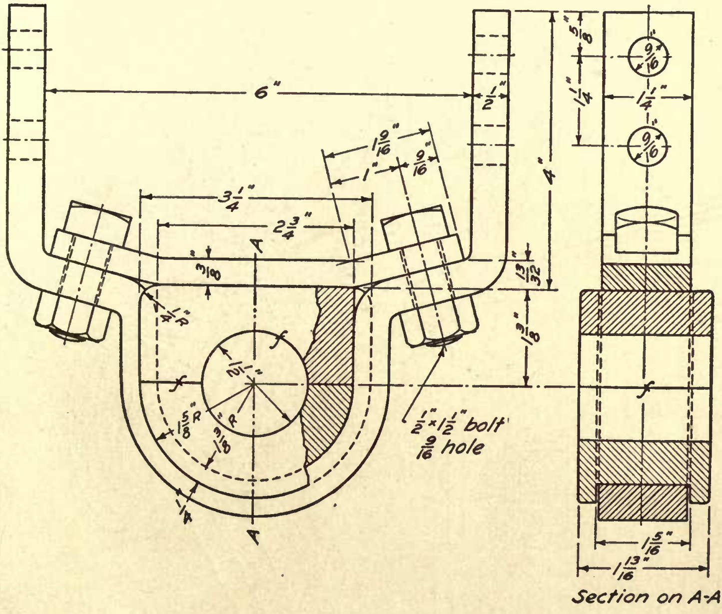


Fig. 366.

Suggested sizes (a) 24″ dia. 6″ face 2″ bore.
(b) 42″ dia. 14″ face 3 7/16″ bore.
(c) 20″ dia. 10″ face 2 3/16″ bore.
(d) 12″ dia. 16″ face 2 7/16″ bore.
(e) 60″ dia. 8″ face 3 15/16″ bore.
(f) 36″ dia. 4″ face 1 7/16″ bore.

Prob. 8.—Working drawing of column base, from Fig. 361.

Prob. 9.—Working drawing of a column base with $G = 7\ 1/2''$ and $H = 10''$, to carry 137,000 lbs., assuming

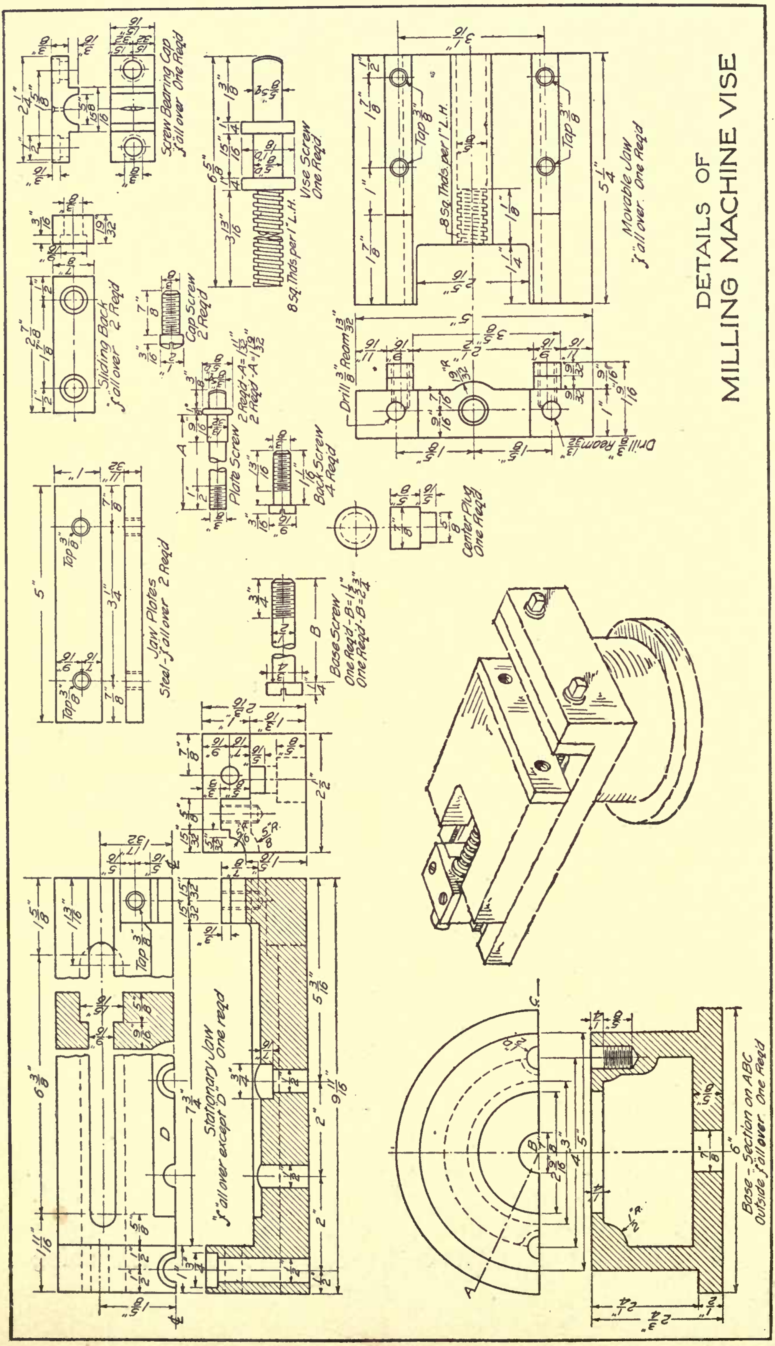

DETAILS OF
MILLING MACHINE VISE
Screw Bearing Cap ƒ all over One Req'd
Sliding Back ƒ all over 2 Req'd
Jaw Plates Steel-ƒ all over 2 Req'd
Cap Screw 2 Req'd
Vise Screw One Req'd
Back Screw 4 Req'd
Center Plug One Req'd
Movable Jaw ƒ all over. One Req'd
Stationary Jaw ƒ all over except D One req'd
Base - Section on ABC Outside ƒ all over One Req'd

Fig. 367.

the bearing value of foundation to be 300 lbs. per sq. in. Ribs 45 degrees.

Prob. 10.—Working drawing of roof truss from sketch, Fig. 362.

Prob. 11.—Working drawing of cast iron manhole cover, from sketch, Fig. 363.

Prob. 12.—Working drawing of timber trestle, height, 12, 14, 16, 18, or 20 feet, Fig. 364, using timbers of sizes given.

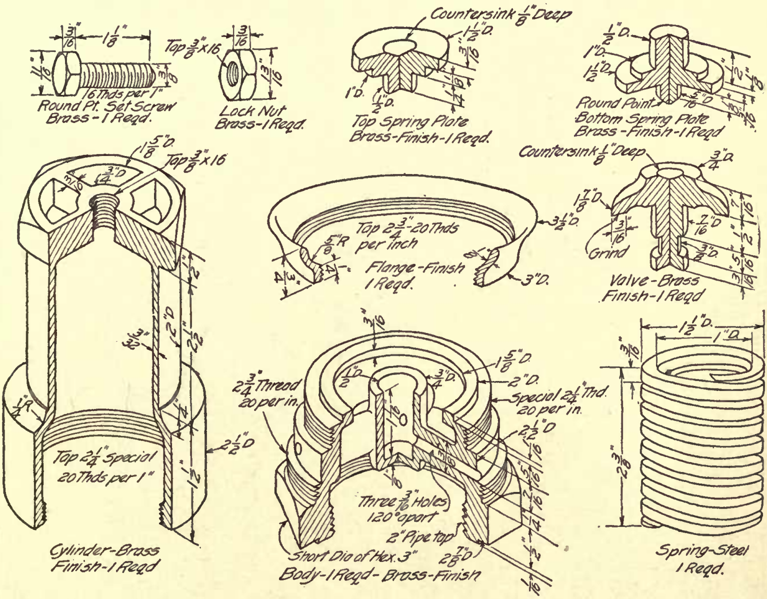


FIG. 368.

Group V.—Assembly and Detail Drawings.

Prob. 1.—Make detail drawings of screw jack, Fig. 365.

Prob. 2.—Make detail drawings of wrought iron hanger, Fig. 366.

Prob. 3.—Make assembly drawing of milling machine vise from details in Fig. 367. The sketch is not a part of the detail drawing but is given to show the arrangement of parts.

Prob. 4.—Make assembly and detail drawings of pop safety valve from the sketch details of Fig. 368.

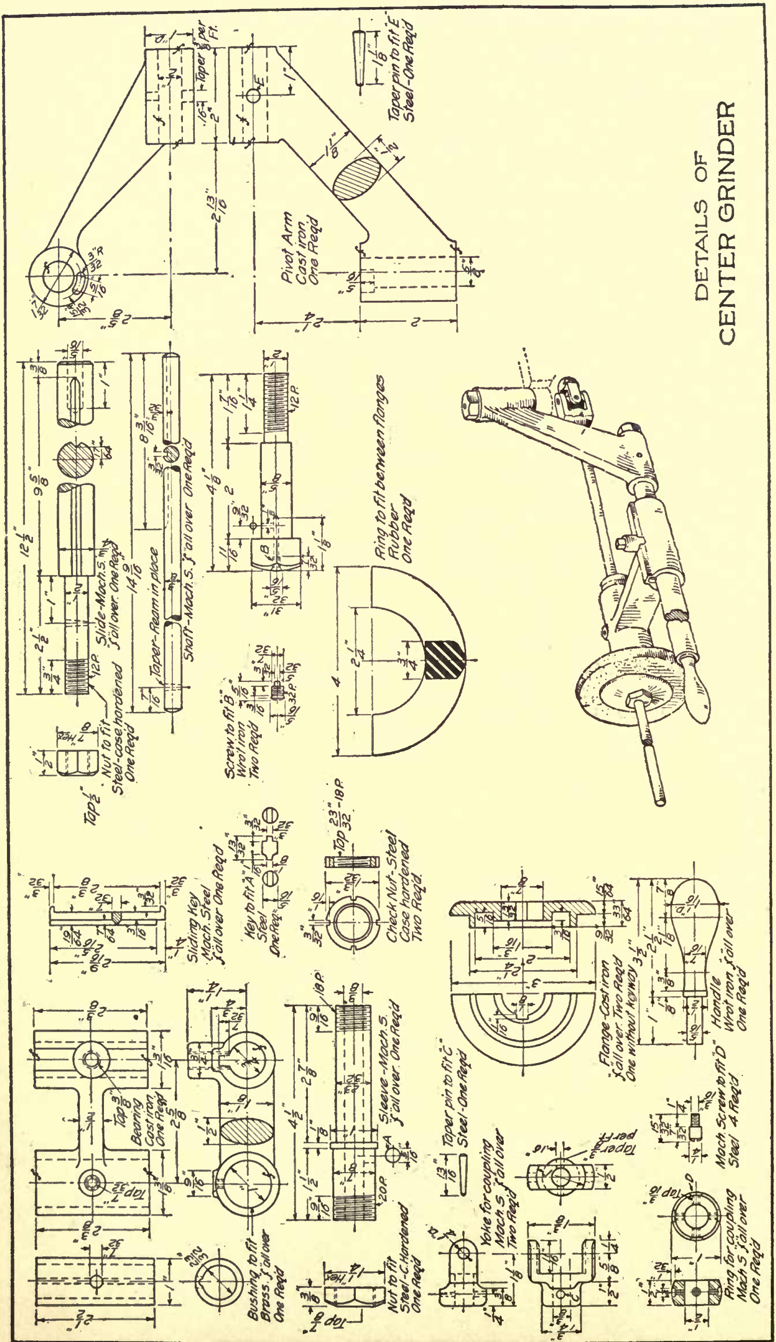

DETAILS OF
CENTER GRINDER
Pivot Arm
Cast Iron
One Req'd
Ring to fit between flanges
Rubber
One Req'd
Slide-Mach. S.
Shaft-Mach. S.
Taper-Ream in place
Sliding Key
Mach. Steel
Check Nut-Steel
Case hardened
Two Req'd
Handle
Wro't Iron
One Req'd
Bearing
Cast Iron
One Req'd

FIG. 369.

Prob. 5.—Make assembly drawing of center grinder, from detail drawing, Fig. 369.

Prob. 6.—Make assembly drawing of friction clutch shifter, from detail drawing, Fig. 308. Its arrangement is shown in sketch, Fig. 370.

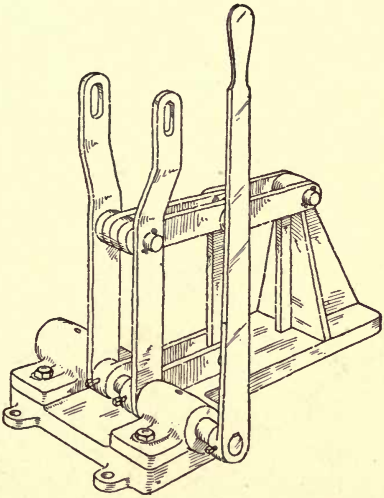


FIG. 370.

Prob. 7.—Make detail drawings of grinder, from assembly drawing, Fig. 371.

Prob. 8.—Make assembly drawing of gas engine mixer from details of Fig. 372.

Group VI.—Checking.

Prob. 1.—Fig. 373 is incorrect in several places both in drawing and dimensions. Check it for errors, following the system given on page 178, and report the errors and corrections on a separate sheet.

Prob. 2.—Check Fig. 374 in the same way.

Group VIII.—Miscellaneous.

Prob. 1.—A patent office drawing, on Bristol board, from an assigned model or sketch. Reference, Chapter XIV.

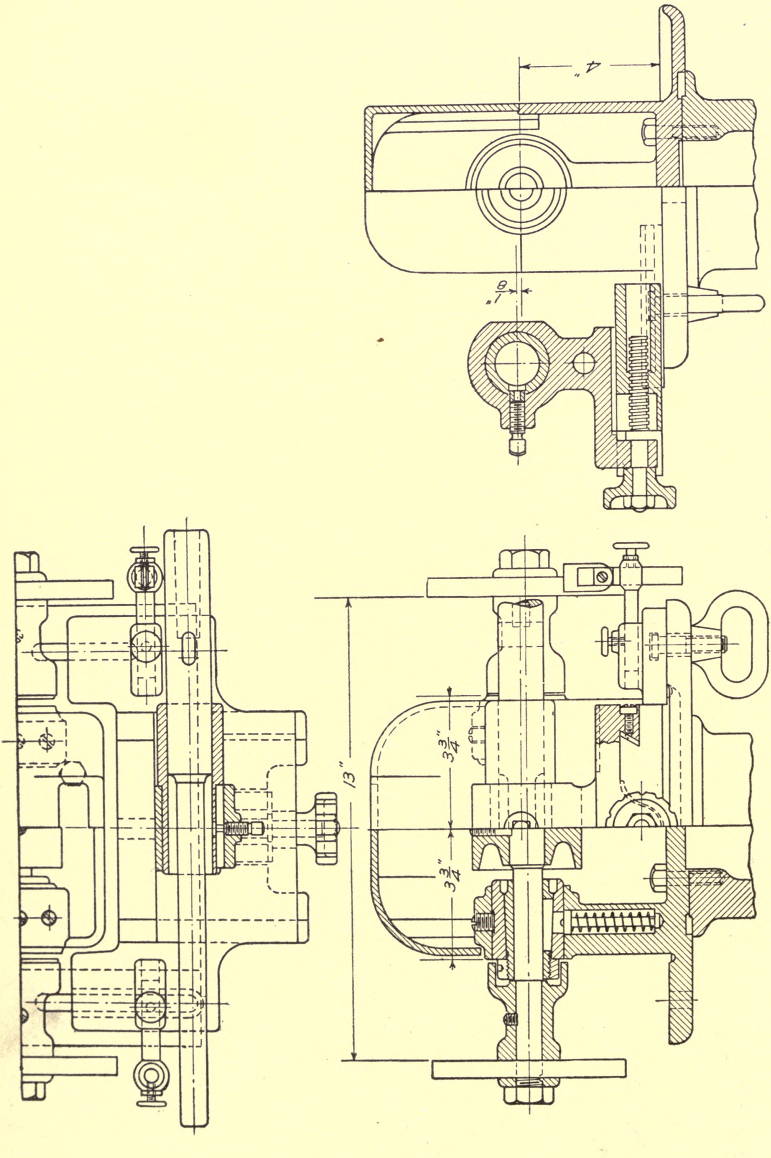


Fig. 371.

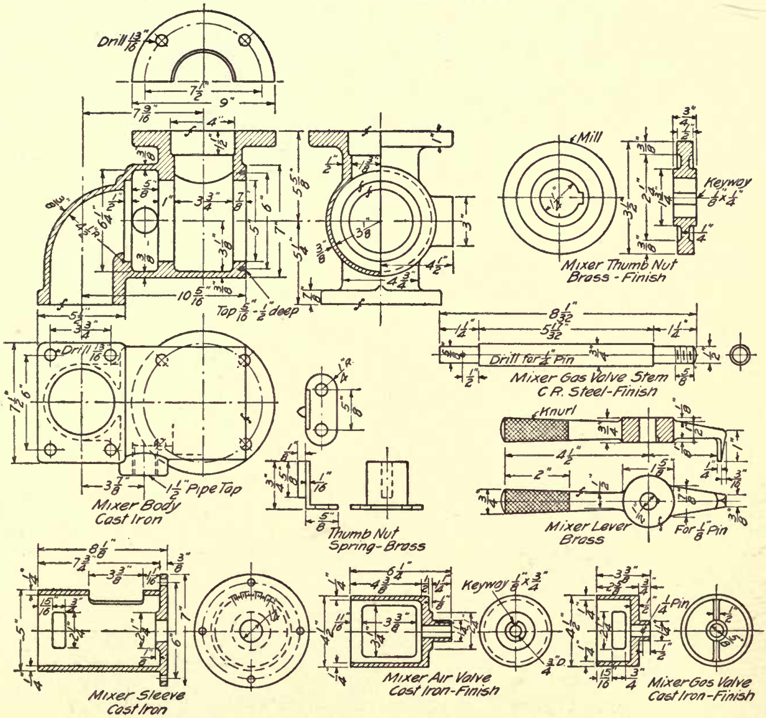


FIG. 372.

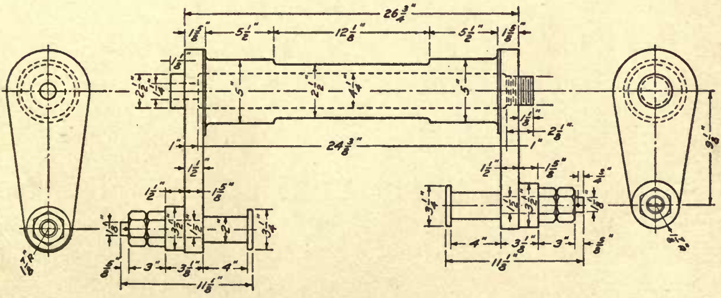


FIG. 373.—An incorrect drawing to be checked for errors.

Prob. 2.—A sheet metal problem, to be drawn, developed and dimensioned, from specifications assigned.

Prob. 3.—A plan of building or room, to be measured and drawn. Reference, Chapter XI.

Prob. 4.—A problem in furniture designing.

Prob. 5.—A problem in structural drawing.

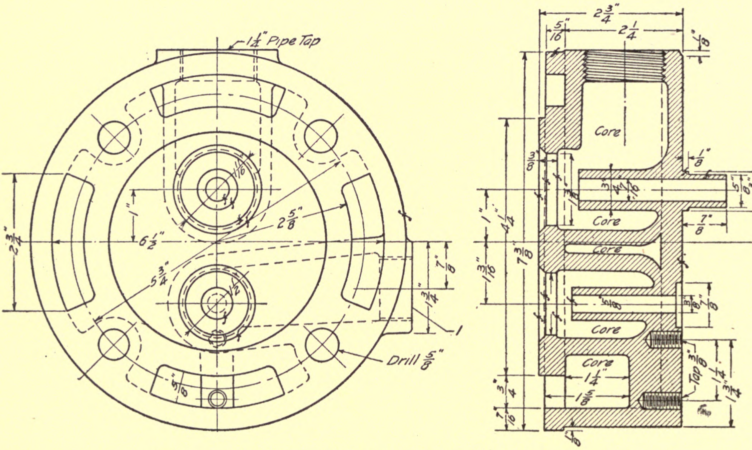


FIG. 374.—An incorrect drawing to be checked for errors.

CHAPTER X.

TECHNICAL SKETCHING.

From its long use in connection with art the word "sketch" has come to suggest the impression of a free or incomplete or careless rendering of some idea, or some mere note or suggestion for future use. This meaning is entirely misleading and wrong in the technical use of the word. A sketch is simply a working drawing made freehand, without instruments, the quick expression of graphic language, but in information adequate and complete.

So necessary to the engineer is the training in freehand sketching, it might almost be said in regard to its importance that the preceding nine chapters have all been in preparation for this one. Such routine men as tracers and detailers may get along with skill and speed in mechanical drawing, but the designer must be able to sketch his ideas with a sure hand and clear judgment. In all mechanical thinking in invention, all preliminary designing, all explanation and instructions to draftsmen freehand sketching is the mode of expression.

It represents the mastery of the language, gained, only after full proficiency in mechanical execution, and is the mastery which the engineer, and inventor, designer, chief draftsman, and contractor, with all of whom time is too valuable to spend in mechanical execution, must have.

It may be necessary to go a long distance from the drawing room to get some preliminary information and the record thus obtained would be valueless if any detail were missing or obscure. Mistakes or omissions that would be discovered quickly in making an accurate scale drawing may easily be overlooked in a freehand sketch, and constant care must be observed to prevent their occurrence.

Sometimes, if a piece is to be made but once a sketch is used as a working drawing and afterward filed.

The best preliminary training for this work is the drawing in the public schools, training the hand and eye to see and represent form and proportion. Those who have not had this preparation should practice drawing lines with the pencil, until the hand obeys the eye to a reasonable extent.

The pencil should be held with freedom, not close to the point,

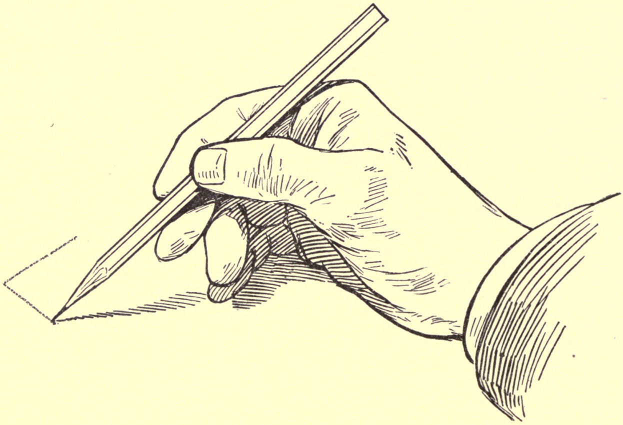


FIG. 375.—Sketching a vertical line.

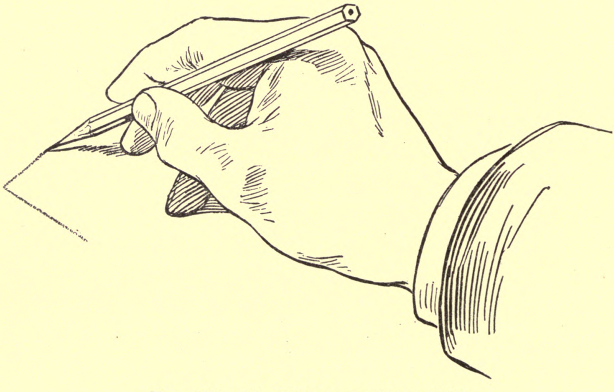


FIG. 376.—Sketching a horizontal line.

vertical lines drawn downward, Fig. 375, and horizontal lines from left to right, Fig. 376.

An H or 2H pencil sharpened to a long conical point, not too sharp, a pencil eraser, to be used sparingly, and paper, either in note book, pad, or single sheet clipped on a board, are all the materials needed.

In making working sketches from objects a two-foot rule and calipers are necessary. Other machinists' tools, a try square, surface gauge, depth gauge, thread gauge, etc., are very convenient. The draftsman's triangle may often be used in place of a square. Sometimes a plumb line is of service. Much ingenuity is often required to get dimensions from an existing machine.

Sketches are made in orthographic, axonometric, or perspective drawing, depending upon the use which is to be made of them. Sketches of machine parts to be used in making working drawings, etc., would be made in orthographic; explanatory, or illustrative sketches might be made in axonometric or perspective.

The best practice is obtained by sketching from castings, machine parts, or simple machines, and making working drawings from the sketches without further reference to the object. In class work a variation may be introduced by exchanging the sketches so that the working drawing is made by another student. This emphasizes the necessity of putting down all the information necessary, and not relying on memory to supply that missing; and working with the idea that the object is not to be seen after the sketch is made. A most valuable training in the observation of details is the sketching from memory a piece previously studied. It is an excellent training in sureness of touch to make sketches directly in ink, perhaps with fountain pen.

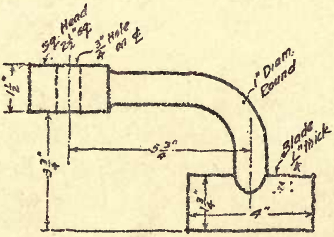


Fig. 377.

Sketching in Orthographic Projection.

The principles of projection and all the rules for working drawings are to be remembered and applied here.

The object should be studied and the necessary views decided upon. In some cases fewer views would be made in the sketch than in the working drawing, as a note in regard to thickness or shape of section might save a view, Fig. 377. In other cases additional views may be sketched rather than complicate the figures by added lines which would confuse a sketch, although the same lines might be perfectly legible in a scale drawing.

In beginning a sketch always start with center lines or datum lines, and remember that the view showing the contour or characteristic shape is to be drawn first. This is generally the view showing circles if there are any.

In drawing on plain paper, the location of the principal points, centers, etc., should be marked so that the sketches will fit the sheet, and the whole sketch with as many views, sections and auxiliary views as are necessary to describe the piece, drawn *without taking any measurements*, but in as nearly correct proportion as the eye can determine.

An object should of course be represented right side up, *i.e.*, in its natural working position. If symmetrical about an axis, often one-half only need be sketched. Circles may be drawn with some accuracy by marking on the center lines points equidistant from the center.

Often fragmentary auxiliary views or sections aid in explaining construction. The rules of projection are to be broken if any advantage may be gained.

If a whole view cannot be made on one page it may be put on two, each being drawn up to a break line used as a datum line.

Sketches should be made entirely freehand, no ruled lines being used.

Dimension Lines.

After the sketching of the piece is entirely finished it should be gone over and dimension lines for all the dimensions needed for the construction added, drawing extension lines and arrow heads carefully and checking to see that none are omitted, but still *making no measurements.*

Dimensions.

Up to this stage the object has not been handled and the drawing has been kept clean. The measurements for the dimensions indicated on the drawing may now be added. The two-foot rule will serve for most dimensions. Never use the draftsman's scale for measuring castings. Its edge will be marred and it will be soiled. The diameters of holes may be measured with the inside calipers. It is often necessary to lay a straight edge across a surface as in Fig. 378. In measuring the distance between centers of two holes of the same size measure from edge to corresponding edge. Always measure from finished surfaces if possible. Judgment must be exercised in measuring rough castings so as not to record inequalities due to the foundry. Fig. 379 illustrates measuring a curve by offsets.

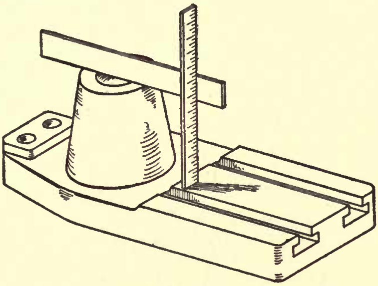


FIG. 378.

It is better to have too many dimensions rather than too few. It is a traditional mistake of the beginner to omit a vital figure.

Add all remarks and notes that may seem to be of any value at all.

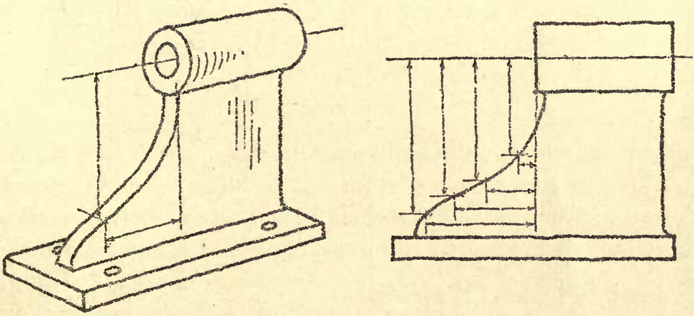


FIG. 379.—Measurements by offsets.

The title should be written on the sketch, and for class sketches the amount of time spent.

Always date every sketch. Valuable inventions have been lost through the inability to prove priority, because the first sketches had not been dated. In commercial work the draftsman's notebook with its sketches and calculations is preserved as a permanent record, and sketches should be made so as to stand the test of time, and be legible after the details of their making have been forgotten.

Cross Section Paper.

Sketches are often made on coordinate paper ruled faintly in sixteenths, eighths or quarter inches, either simply as an aid in drawing straight lines and judging proportions; or assigning

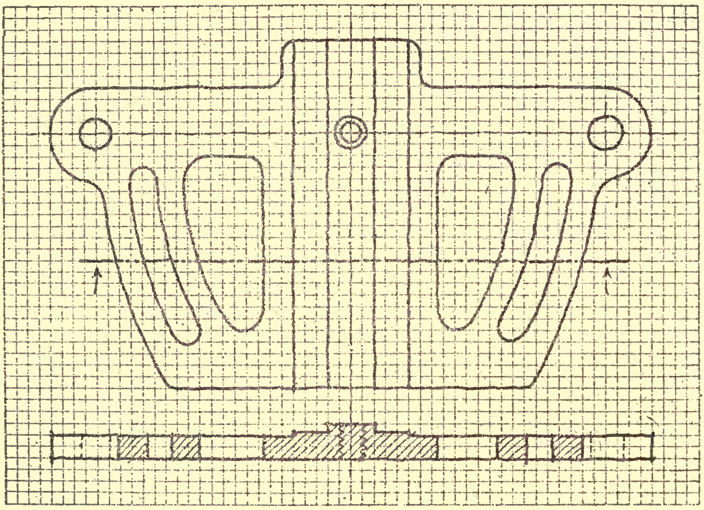


Fig. 380.—Sketch on coördinate paper.

suitable values to the unit spaces, and drawing to approximate scale. In the latter case a sufficient number of measurements must be taken while the sketch is being made, to permit of its being laid off on the coordinate paper. Fig. 380 is an illustration.

Sketching by Pictorial Methods.

An axonometric, oblique or perspective sketch of an object or of some detail of construction will often explain it when the orthographic projection cannot be read intelligently by a workman. Often again a pictorial sketch may be made more quickly and serve as a better record than orthographic views of the same piece would do, and the draftsman who can make a pictorial sketch with facility will find abundant opportunity for its advantageous use.

Axonometric Sketching.

Since measurements are not made on sketches there is absolutely no advantage in sketching on isometric axes 120 degrees apart and making an unnecessary distortion. A much better effect is gained and the distortion greatly lessened by drawing the cross axes at a much smaller angle with the horizontal, Fig. 381, and foreshortening them until satisfactory to the eye. It is legitimate in such an isometric sketch still further to decrease the effect of distortion by slightly converging the receding lines. Objects of rectangular outline are best adapted to sketching in axonometric projection.

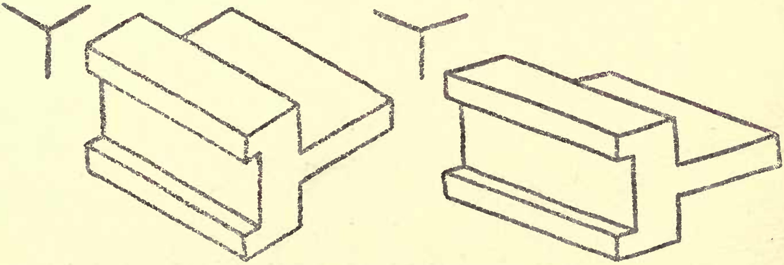


FIG. 381.—120° axes and flattened axes compared.

When it is important to show the top surface the axes may be drawn at greater angles to the horizontal, and the vertical axis foreshortened, thus tipping the object forward as in Fig. 382.

Some care must be exercised in adding dimensions to a pictorial sketch. The extension lines must always be either in or perpendicular to the plane on which the dimension is being given.

Oblique Sketching.

The advantage of oblique projection in preserving one face without distortion is of particular value in sketching, and the painful effect of this kind of drawing done mechanically may be greatly lessened in sketching, by foreshortening the cross axis to a pleasing proportion, Fig. 383. By converging the lines parallel to the cross axes, the effect of parallel perspective is obtained. This converging in either isometric or oblique is sometimes called "fake perspective."

Perspective Sketching.

A sketch made in perspective will of course give the best effect pictorially. As we do not in this book take up the subject of mechanical perspective, with its rules and methods, only the phenomena of perspective and their application in freehand sketching can be considered in this connection.

Perspective has already been defined as being the representation of an object as seen by the eye from some particular station point. Geometrically, it is the intersection of the cone of rays

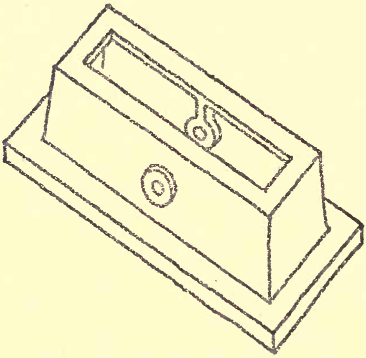


Fig. 382.

from the eye to the object, with the vertical plane, or "picture plane." There is a distinction between "artist's perspective" and "geometrical perspective," in that the artist draws the object as he sees it projected on the spherical surface of the retina of his eye, while geometrical, or mechanical perspective is

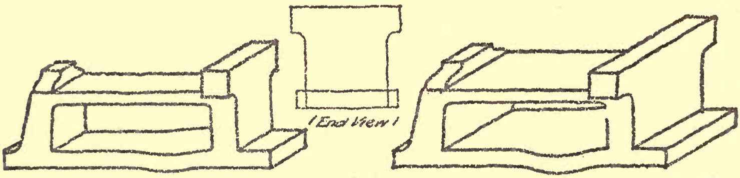


Fig. 383.—Oblique, with and without foreshortening.

projected on a plane, as in a photograph, but except in wide angles of vision the difference is not very noticeable.

The ordinary phenomena of perspective, affecting everything we see, the fact of objects appearing smaller in proportion to their distance from the eye, and of parallel lines appearing to converge as they recede, are of course well known.

The outline of the object in Fig. 384 is drawn from a photograph. It will be noted that the vertical lines remain vertical in the picture, and that the two sets of horizontal lines each appear to converge toward a point called the "vanishing point." These two vanishing points will lie on a horizontal line drawn at the level of the eye, called the "horizon"; and the first rule is, *all horizontal lines vanish on the horizon.*

When the object is turned as in Fig. 384, with its vertical faces at an angle with the picture plane, the drawing is said to be in angular perspective. It is sometimes called "two-point" perspective because of having two vanishing points.

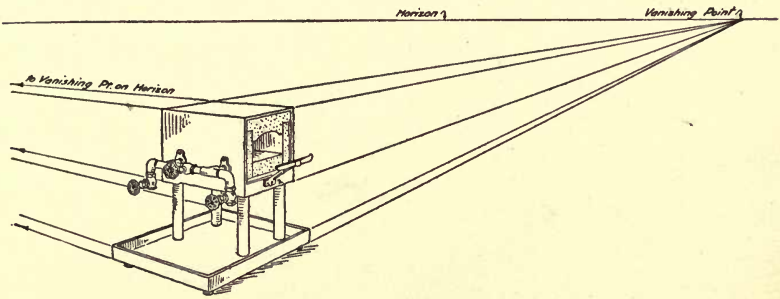


FIG. 384.—Perspective (from photograph).

If the object is turned so that one face is parallel to the picture plane, the horizontal lines on that face and all lines parallel to them would remain horizontal in the picture and would thus have no vanishing point. The object drawn in this position is said to be in parallel, or "one-point" perspective.

In sketching in perspective from the model the drawing is made simply by observation, the directions and proportionate lengths of lines being estimated by sighting and measuring on the pencil held at arm's length; and knowledge of the geometrical rules and principles used only as a check.

With the drawing board or sketch pad held **perpendicular** to the "line of sight" from the eye to the object, the direction of a line is tested by holding the pencil at arm's length **parallel to the board,** rotating the arm until the pencil appears to coincide with the line on the model, then moving it parallel to this position, back to the board.

The apparent lengths of lines are estimated in the same way, holding the pencil in a plane perpendicular to the line of sight, marking with the thumb the length of pencil which covers a line of the model, rotating the arm, with the thumb held in position, until the pencil coincides with another line, and estimating the proportion of this measurement to the second line, Fig. 385.

The sketch should be made lightly, with free sketchy lines, and no lines erased until the whole sketch has been blocked in.

Have the drawing as large as the paper will admit.

In constructing a perspective from an orthographic or other drawing, use may be made of the plan and cone of rays, and the vanishing points. Imagining the eye as located at the station

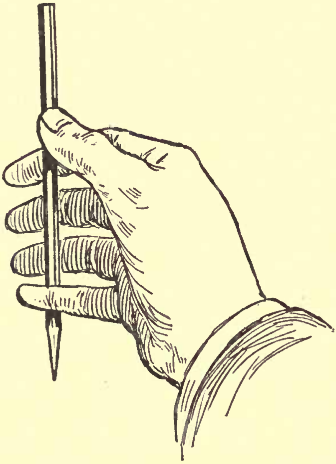


FIG. 385.

point, a little thought will show that the vanishing point of any system of parallel lines is the projection on the picture plane of their infinite ends, the eye looking farther and farther out, till the line of vision is parallel to the lines. Hence, *the vanishing point of any system of parallel lines is found by drawing from the station point a line parallel to the given lines and finding where it pierces the picture plane.*

A line drawn from the station point perpendicular to the picture plane pierces it in a point called the "center of vision." Evidently *all lines perpendicular to the picture plane will vanish in the center of vision.* This is the basis of parallel perspective.

An object in parallel perspective with one face in the picture plane is shown at *A*, Fig. 386. At *B* is shown the top view of *A* with the cone of rays. *C* shows the picture plane detached and set forward in order that it may not interfere with the plan when revolved. *D* is the top view of *C* after the picture plane has been revolved.

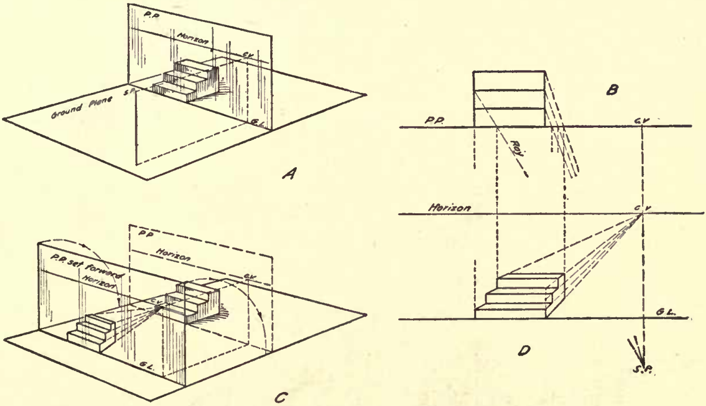


Fig. 386.—Parallel perspective.

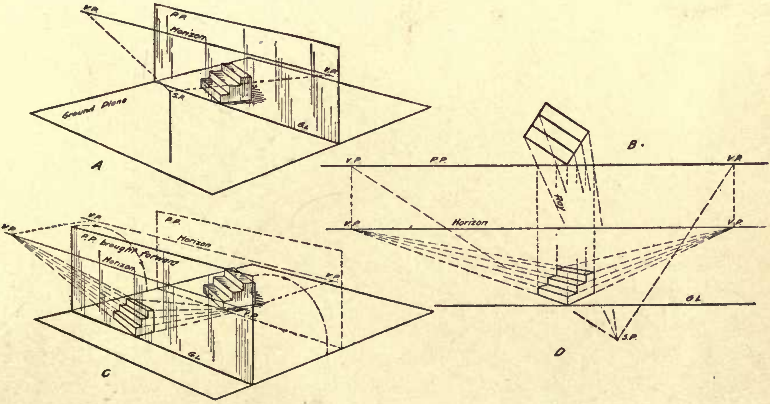


Fig. 387.—Angular perspective.

It will be noticed that the edges perpendicular to the picture plane vanish in the center of vision, and that their perspective lengths are found by dropping to them points the of intersection of the cone of rays with the picture plane.

Direct measurements can be made only in the picture plane.

The station point should be taken at a distance at least twice the length of the longest side.

Fig. 387 is a series illustrating an object in angular perspective. *A* the object, with one corner in the picture plane; *B* the plan,

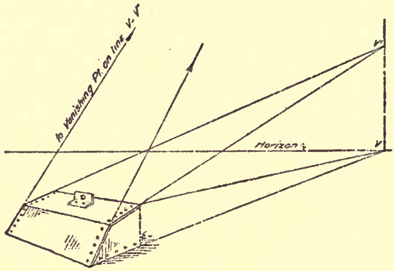


FIG. 388.

showing the finding of the vanishing points for the two series of horizontal lines by drawing lines through the station point parallel to them; *C* the picture plane moved forward bringing with it

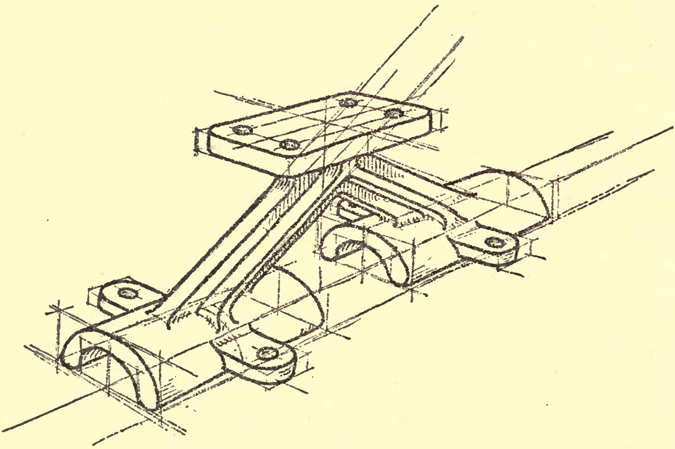


FIG. 389.—A perspective sketch.

the horizon and vanishing points; *D* the picture plane revolved. The figure illustrates the general case. It is usual, in practice, to take the S. P. directly in front of the corner that is in the P. P.

Fig. 388 shows that the vanishing point of a system of oblique lines is on a perpendicular from the vanishing point of their projections.

Fig. 389 gives an application of perspective sketching, showing construction.

Fig. 390 contains a selection of perspective sketches to be sketched in orthographic.

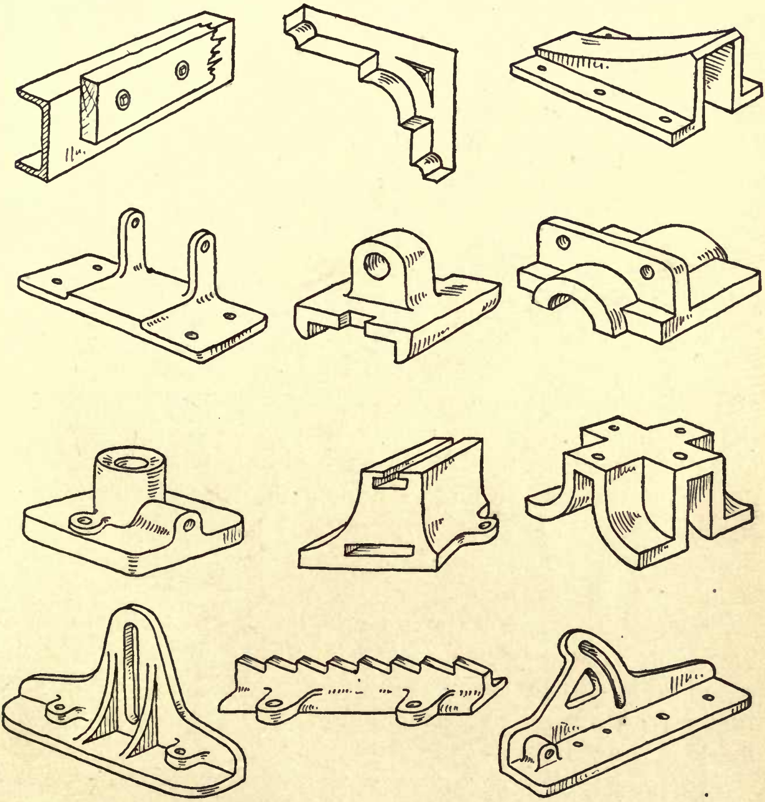


FIG. 390.—Perspective sketches.

CHAPTER XI.

The Elements of Architectural Drawing.

It is entirely beyond the scope of this book to take up architectural designing. But in the application by the architect, of engineering drawing as a language, there are idioms and peculiarities of expression, with which all engineers should be familiar, as in the interrelation of the professions they are often required to read or work from architects' drawings, or to make the drawings for special structures.

Characteristics of Architectural Drawing.

The general principles of drawing are the same for all kinds of technical work. Each profession requires its own special application of these principles, and the employment of particular methods, symbols and conventions.

In architectural drawing the necessary smallness of scale makes it impossible to represent the different parts exactly, and the drawings thus become largely conventional. The necessary notes for their explanation, and the information regarding the details of material and finish are too extensive to be included on the drawings so are written separately, and are called the **specifications.** These specifications have equal importance and weight with the drawings.

Architecture is one of the fine arts, and in an architect's drawings there is an evidence of artistic feeling in their make up, produced in part by the freehand work and lettering upon them, that gives them an entirely different appearance from a set of machine drawings.

The present day fad of over running corners is however a rather senseless affectation.

Kinds of Drawings.

Architectural drawings may be divided into three general classes:

(1) Display and competitive drawings.
(2) Preliminary sketches.
(3) Working Drawings.

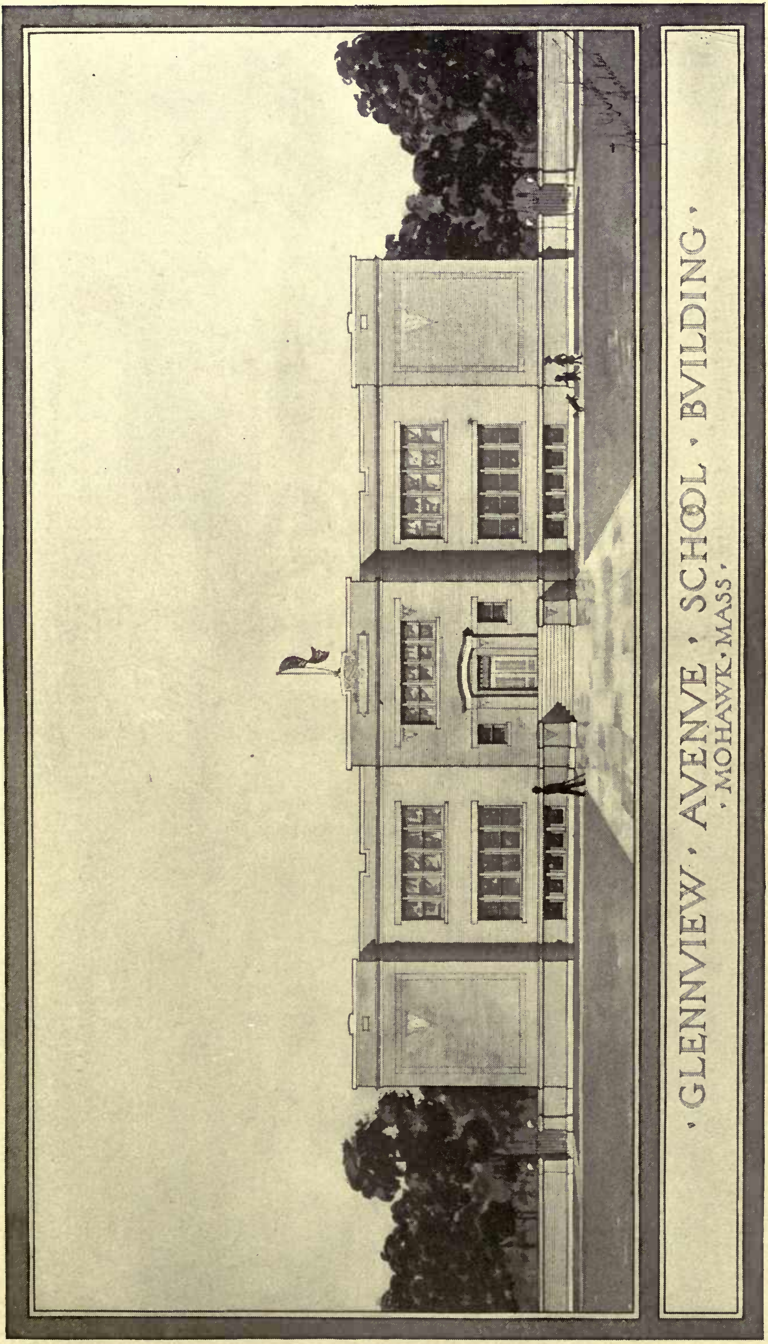


Fig. 391.—Rendered elevation.

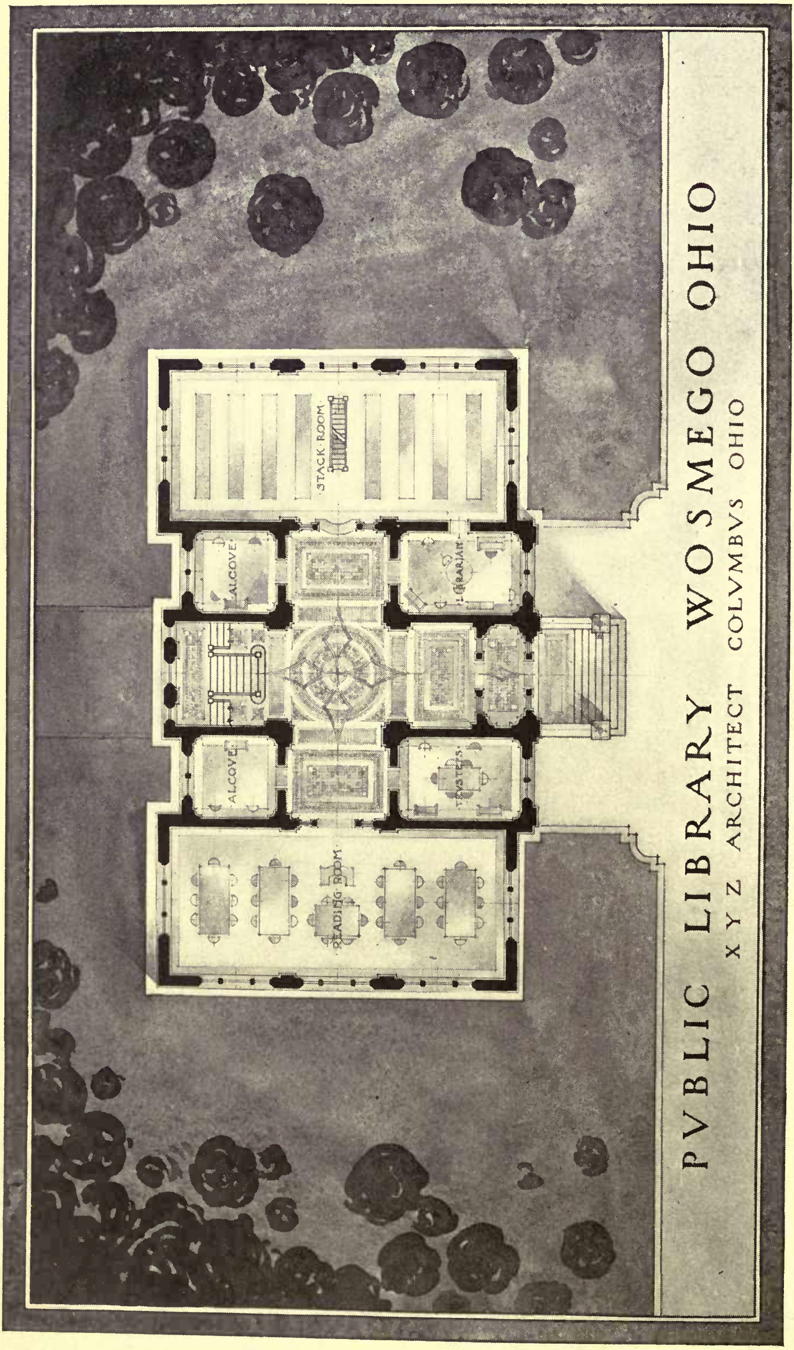


FIG. 392.—Plan, with poché and mosaic.

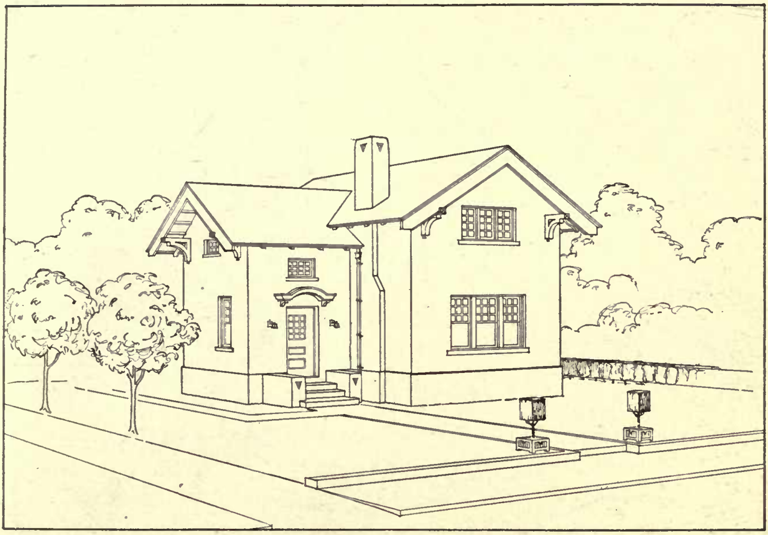


FIG. 393.—Perspective in ruled outline.

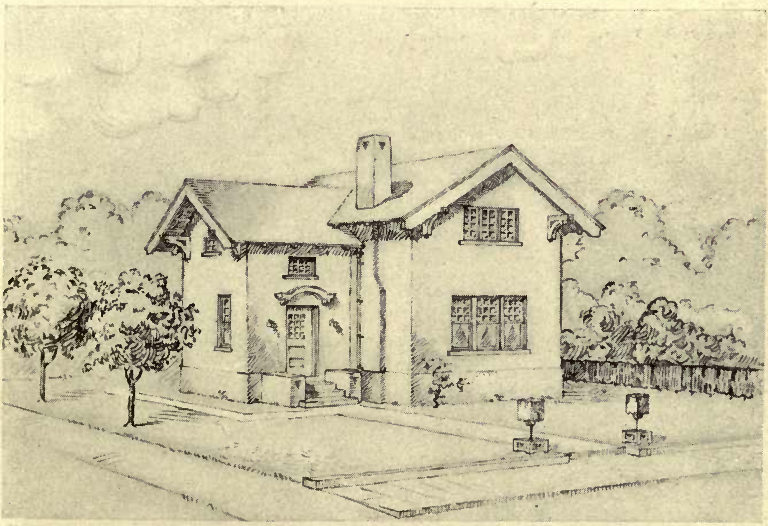


FIG. 394.—A pencil rendering.

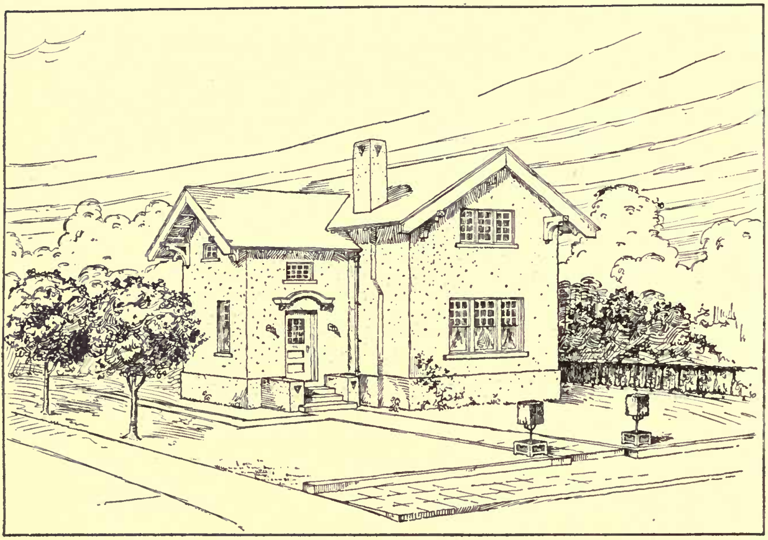


FIG. 395.—A pen drawing.

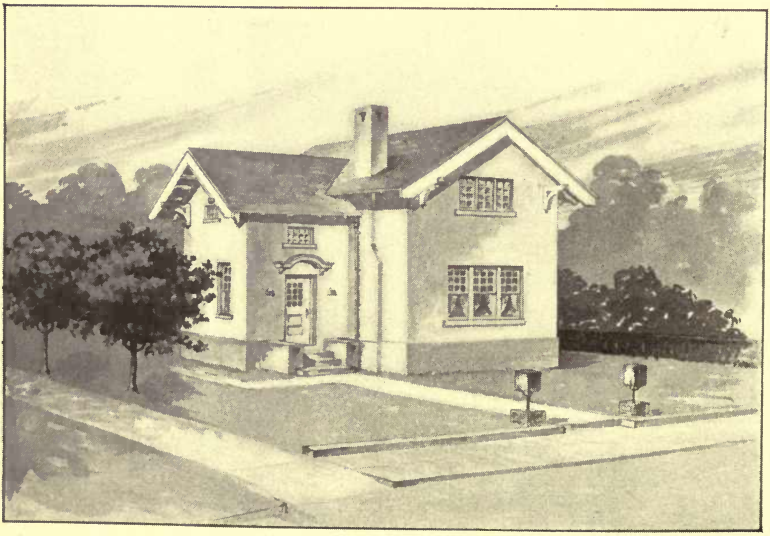


FIG. 396.—A wash drawing.

Display Drawings.

The object of *display drawings* is to give a realistic or effective representation of the arrangement and appearance of a proposed building, for illustrative or competitive purposes. They may be either plans and elevations, or may include perspective drawings; and contain little or no structural information. For legibility and attractiveness they are "rendered," generally on Whatman, eggshell, tracing, or other white paper, in some medium, giving the effect of light and shade. Fig. 391 illustrates an elevation rendered in wash, in which a certain perspective effect is added by extending the foreground.

Figures, trees, other buildings, etc., are sometimes introduced on such drawings, not so much for pictorial effect, but to give an idea of the relative size of the buildings.

In rendering plans for display or competitive purposes, tints and shadows are often used to show the plan in relief and to express the ideas of the architect more fully. Fig. 392 illustrates a plan of this kind, employing poché and mosaic; "poché" meaning simply the blackening of the walls to indicate their relative importance in the composition, and "mosaic" the rendering, in light lines and tints, of the floor design, furniture, etc., on the interior, and the walks, drives and gardening of the exterior.

The architect must be familiar with perspective drawing, as he uses it both in the preliminary study of his problem and to show the client the finished appearance of the proposed structure. Perspectives are rendered according to the purpose of the drawing. Four different methods are illustrated. Fig. 393 is a ruled outline, Fig. 394 a pencil drawing, usually done on tracing paper; Fig. 395 a pen drawing, and Fig. 396 a wash drawing, done either in monochrome or in color. In rendering a perspective in water color it is best to transfer it by rubbing, as described on page 268, in order to preserve the surface of the paper.

Preliminary Sketching.

The architects' designing problems present so many solutions that a great amount of preliminary sketching is necessary, and the architectural draftsman must be facile with the pencil. These schemes are carried on first in very small sketches, not to scale, and afterward worked up enlarging them in sketches to scale. Tracing paper is very desirable for this work as one sketch can be made over another, thus saving time in laying out, and enabling the preservation of all the different solutions. The final preliminary sketches are submitted to the client, and should give all the general dimensions. In preparing these sketches the important consideration to be kept in mind is that the client is usually a person not accustomed to reading a drawing, and that they must therefore be particularly clear and free from ambiguity.

Tracing paper drawings are often mounted for display either by "tipping" or "floating," as described on page 267.

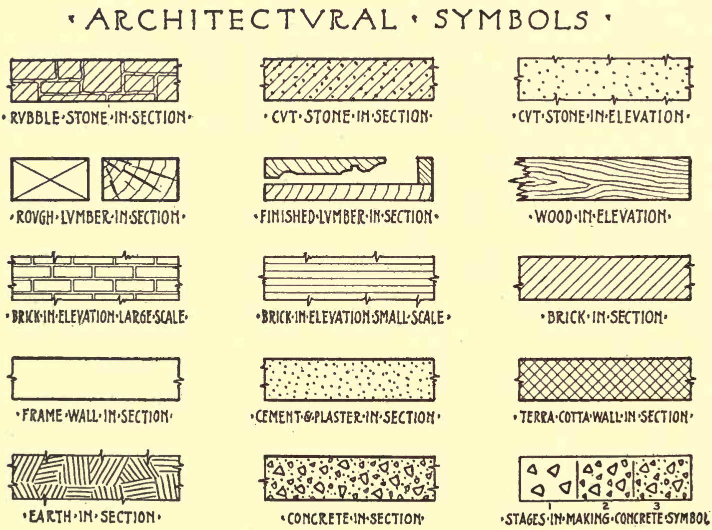


Fig. 397.—Symbols for building materials.

Working Drawings.

All the general principles in Chapter IX regarding working drawings are applicable to architectural working drawings. The assembly drawings are plans, elevations and sections. The plans of a building of the size of an ordinary house would be drawn to the scale of $1/4'' = 1'$, larger buildings to $1/8'' = 1'$. In order to keep the drawings to convenient working size, only one view, usually, is drawn on a sheet.

Plans.

A floor plan is a horizontal section at a distance above the floor varying so as to cut the walls at a height which will best show

FIG. 398.—Standard wiring symbols.

the construction. The cut would thus evidently cross all openings no atmter at what height they were from the floor. The joist system or construction of the floor, and also any information regarding the ceiling above, as beams, gas and electric outlets, etc., may be shown on the same drawing.

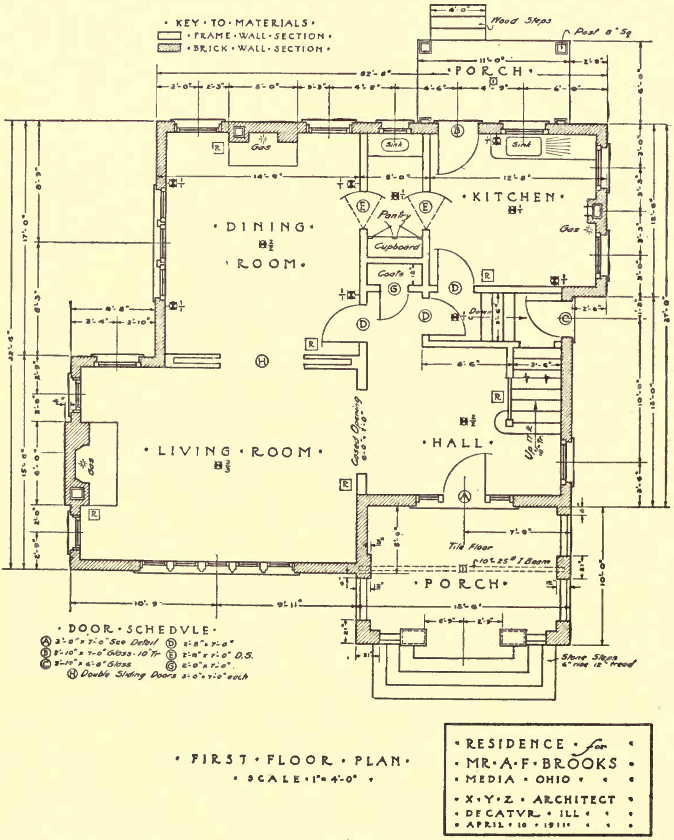


Fig. 399.—A residence floor plan.

The different details such as windows, doors, etc., must be indicated by conventional representation, using symbols, which are readily understood by the contractors who have to read the drawings. A wall, of whatever material, is shown by two lines giving its thickness, with the space between generally section-lined (or tinted) to indicate the material. A code of conventional symbols, representing good practice, is given in Fig. 397. As there is no universally accepted standard of symbols, a key to materials represented in section should always be shown on the drawing.

Fig. 398 contains the standard symbols for wiring plans.

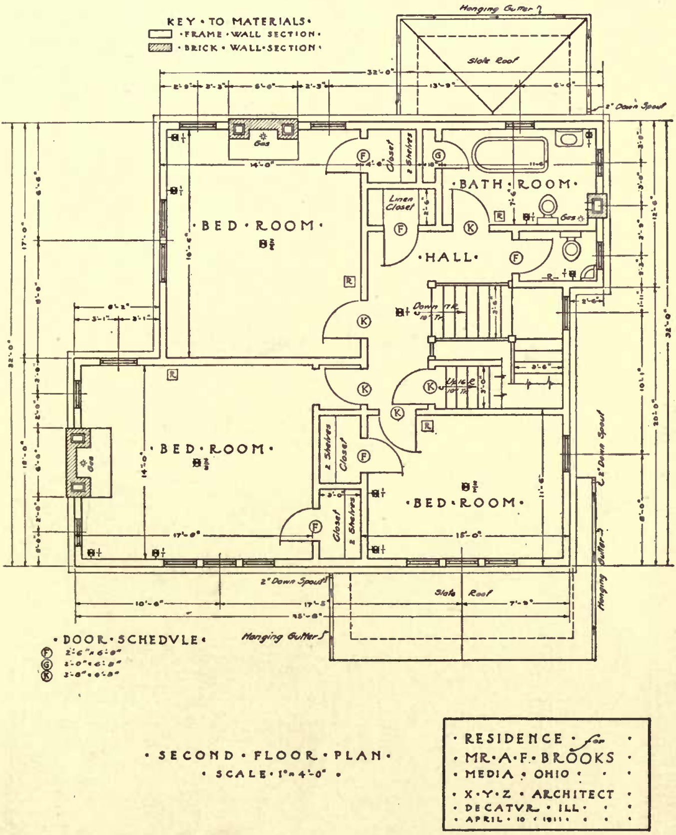


Fig. 400.—A residence floor plan.

Figs. 399 and 400 are representative residence floor plans, showing the application of a number of conventions, and Fig. 401 is the plan of an engineering structure.

Elevations.

An elevation is a vertical projection showing the front, side or rear view of a structure, giving the heights and exterior treat-

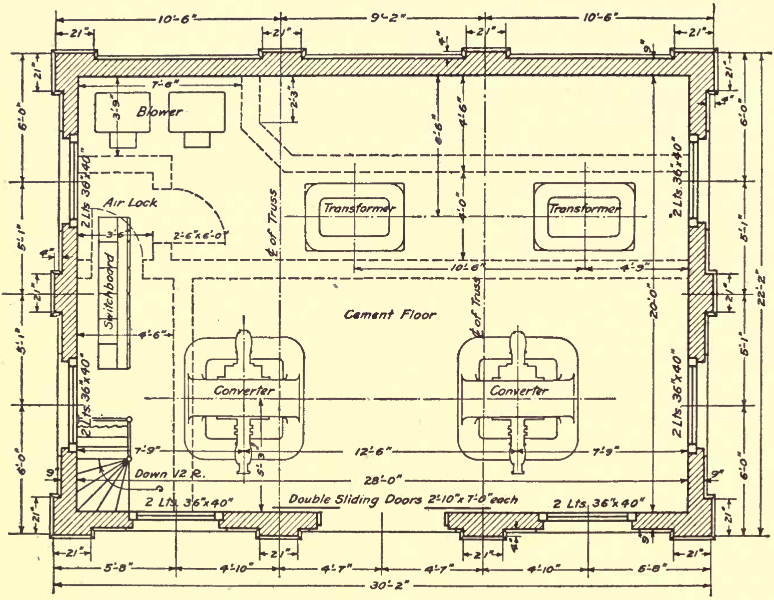


FIG. 401.—Floor plan of sub-station.

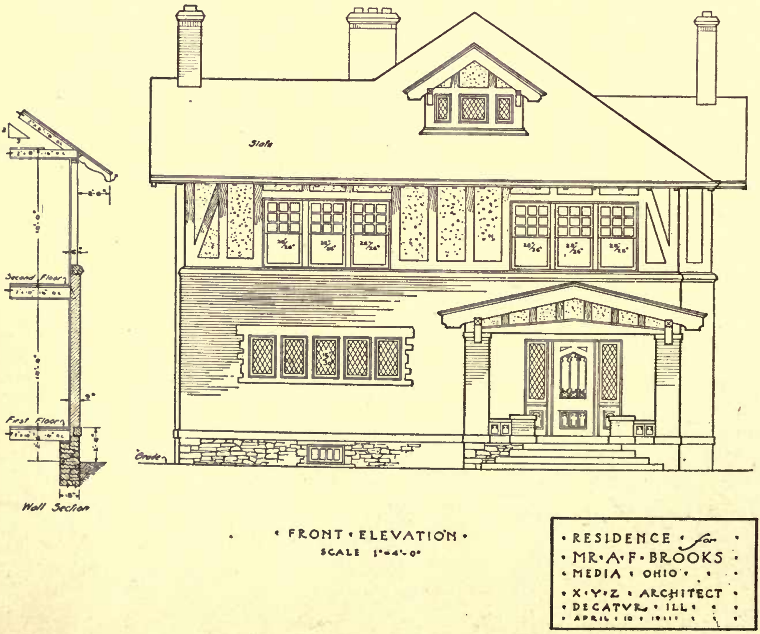


FIG. 402.—An elevation, with wall section.

ment. The visualizing power must be exercised to imagine the actual appearance or perspective of a building from its elevations. Roofs in elevation are thus often misleading to persons unfamiliar with drawing, as their appearance in projection is so different from the real appearance of the building when finished.

Only those dimensions should be put on elevations as are not possible to show on the other drawings.

Fig. 402 is an elevation, with wall section of the house whose plans are shown in Figs. 399 and 400.

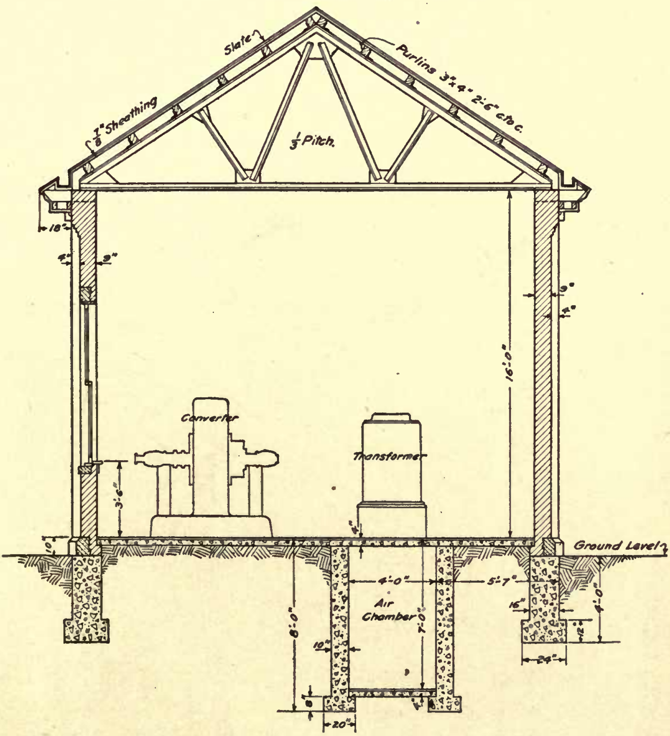


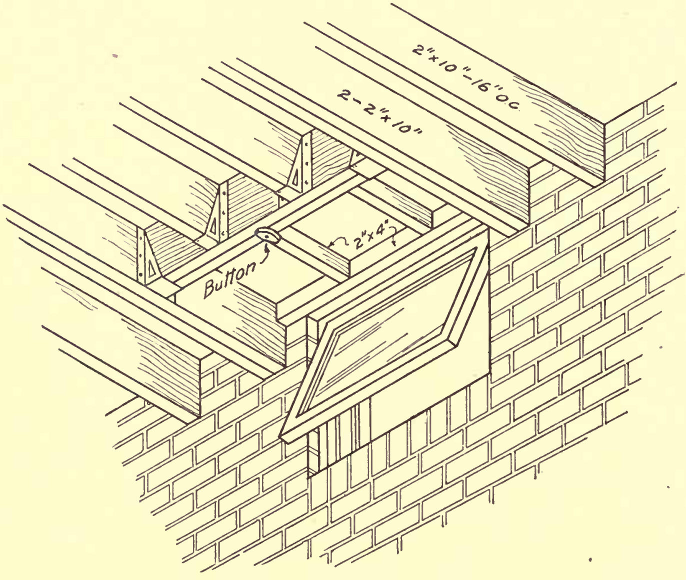
FIG. 403.—Section of sub-station.

Sections.

A section is an interior view on a vertical cutting plane and is used primarily to indicate the heights of the floors and different parts, and to show the construction and architectural treatment of the interior. In a simple structure a part section or "wall section," shown with the elevation, as in Fig. 402, is often sufficient. This cutting plane, as the horizontal, need not be continuous, but may be broken so as to include as much information as possible. Fig. 403 is a full section, or sectional elevation of the sub-station shown in plan in Fig. 401.

Details.

Architectural details are made to explain peculiar constructions or to give a full graphic description of any part. Often



· DETAIL · OF · FRAMING · AROUND BASEMENT · WINDOWS ·
SCALE $\frac{1}{2}$" = 1'-0"

Fig. 404.—An isometric detail.

some peculiarity of framing may be explained easily by an isometric detail, as Fig. 404. Stair details and the like may be shown with sufficient clearness, as in Fig. 405, to the scales of 3/4″ or 1″. Mouldings and other mill work details are generally made full size. The turned or revolved section is often of use in showing moulding sections in position.

Dimensioning.

As in machine drawing, the correct dimensioning of an architectural drawing requires a knowledge of the methods of building construction. The dimensions should be placed so as to be the most convenient for the workman, should be given from and to accessible points, and chosen so that commercial variation in the sizes of materials will not affect the general dimensions.

A study of the dimensioning on the figures of this chapter will be of value.

The statement that the notes were put in the specifications does not at all imply that no notes are to be placed on the

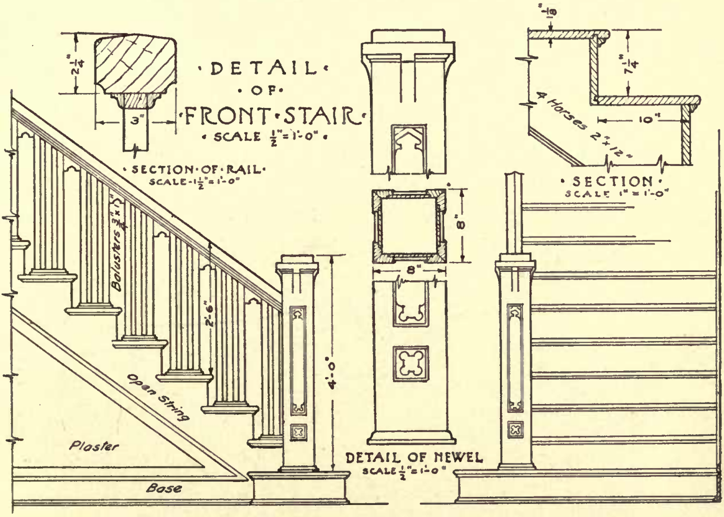


FIG 405.—A stair detail.

drawings. On the other hand, there should be on architectural working drawings clear, explicit notes in regard to material, construction and finish. The builders are apt to overlook a point mentioned only in the specifications, but as they are using the drawings constantly, will be sure to see a reference or note on the drawing of the part in question.

Lettering.

There are two distinct divisions in the use of lettering by the architect, the first, *Office Lettering*, including all the titles and notes put on drawings for information; the second, *Design Lettering*, covering drawings of letters to be executed in stone or bronze or other material in connection with design.

The Old Roman is the architect's one general purpose letter which serves him with few exceptions for all his work in both divisions. It is a difficult letter to execute properly and the draftsman should make himself thoroughly familiar with its construction, character, and beauty, through a text-book on the subject, before attempting to design inscriptions for permanent structures, or even titles.

Titles on display drawings are usually made in careful Old Roman, and on working drawing, in a rapid single stroke based on Old Roman. For notes the Reinhardt letter is best adapted.

An architectural title should contain part or all of the following items:

(1) Name and location of structure.
(2) Kind of view, as *roof plan, elevation* (sometimes put on different part of sheet).
(3) Name and address of owner or client.
(4) Date.
(5) Scale.
(6) Name and address of architect.
(7) Number (in the set).
(8) Key to materials.
(9) Office record.

CHAPTER XII.

Map and Topographical Drawing.

Thus far in our consideration of drawing as a graphic language we have had to represent the three dimensions of an object, either pictorially or, in the usual case, by drawing two or more views of it. In map drawing, the representation of features on parts of the earth's surface, there is the distinct difference that the drawing is complete in one view, the third dimension (the height) either being represented on this view, or in some cases omitted as not required for the particular purpose for which the map was made.

The surveying and mapping of the site is the first preliminary work in improvements and engineering projects, and it is desirable that all engineers should be familiar with the methods and symbols used in this branch of drawing. Here again, as in our discussion of architectural drawing, we cannot consider the practice of surveying and plotting, or go into detail as to the work of the civil engineer, but we are interested in his use of drawing as a language, and in the method of commercial execution of plats and topographical maps. The titles of several books on plane and topographic surveying are given in Chapter XV.

Maps in general may be classified as follows:

(1) Those on which the lines drawn represent imaginary or unreal lines, such as divisions between areas subject to different authority or ownership, either public or private; or lines indicating geometrical measurements on the ground. In this division may be included plats or land maps, farm surveys, city subdivisions, plats of mineral claims.

(2) Those on which lines are drawn to represent real or material objects within the limits of the tract, showing their relative location, or size and location, depending upon the purpose of the map. When relative location only is required the scale may be small, and symbols employed to represent objects, as houses, bridges or even towns. When the size of the object is an

important consideration the scale must be large and the map becomes a real orthographic top view.

(3) Those on which lines or symbols are drawn to tell the relative elevation of the surface of the ground. These would be called relief maps, or if contours are used with elevations marked on them, contour maps.

Various combinations of these divisions may be required for different purposes. A topographic map, being a complete description of an area, would include 1, 2 and 3, although the term may be used for a combination of any two.

Plats.

A map plotted from a plane survey, and having the third dimension omitted, is called a "plat" or "land map." It is used in the description of any tract of land when it is not necessary to show relief, as in such typical examples as a farm survey or a city plat.

The first principle to be observed in the execution of this kind of drawings is *simplicity.* Its information should be clear, concise and direct. The lettering should be done in single stroke, and the north point and border of the simplest character. The day of the intricate border corner, elaborate north point, and ornamental title is, happily, past, and all such embellishments are rightly considered not only as a waste of time, but as being in extremely bad taste.

A Farm Survey.

The plat of a farm survey should give clearly all the information necessary for the legal description of the parcel of land. It should contain:

(1) Lengths and bearings of the several sides.
(2) Acreage.
(3) Location and description of monuments found and set.
(4) Location of highways, streams, etc.
(5) Official division lines within the tract.
(6) Names of owners of abutting property.
(7) Title and north point.
(8) Certification.

Fig. 406 illustrates the general treatment of this kind of drawing. It is almost always traced and blue printed, and no water lining of streams or other elaboration should be attempted. It is important to observe that the size of the lettering used for the several features must be in proportion to their importance

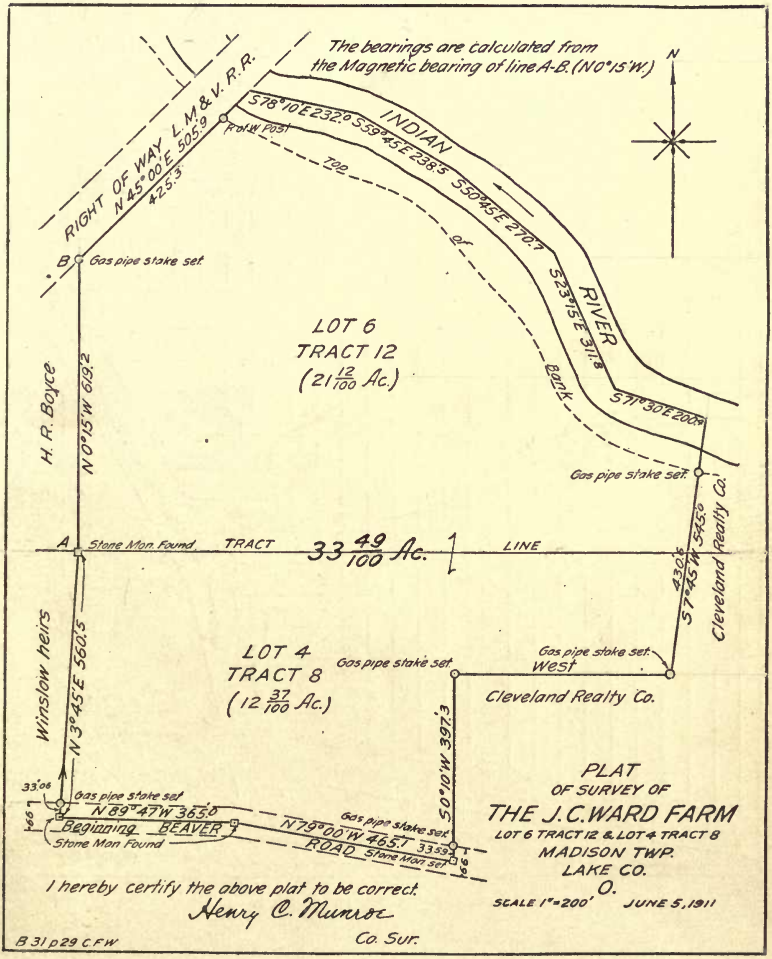


FIG. 406.—A farm plat.

Plats of Subdivisions.

The plats of subdivisions and allotments in cities are filed with the county recorder for record, and must be very complete in their information concerning the location and size of the various lots and parcels composing the subdivisions, Fig. 407. All monuments set should be shown and all measurements of lines and angles given, so that it will be possible to locate any lot with precision.

Sometimes landowners desire to use these maps in display to prospective buyers, and some degree of embellishment is allowable,

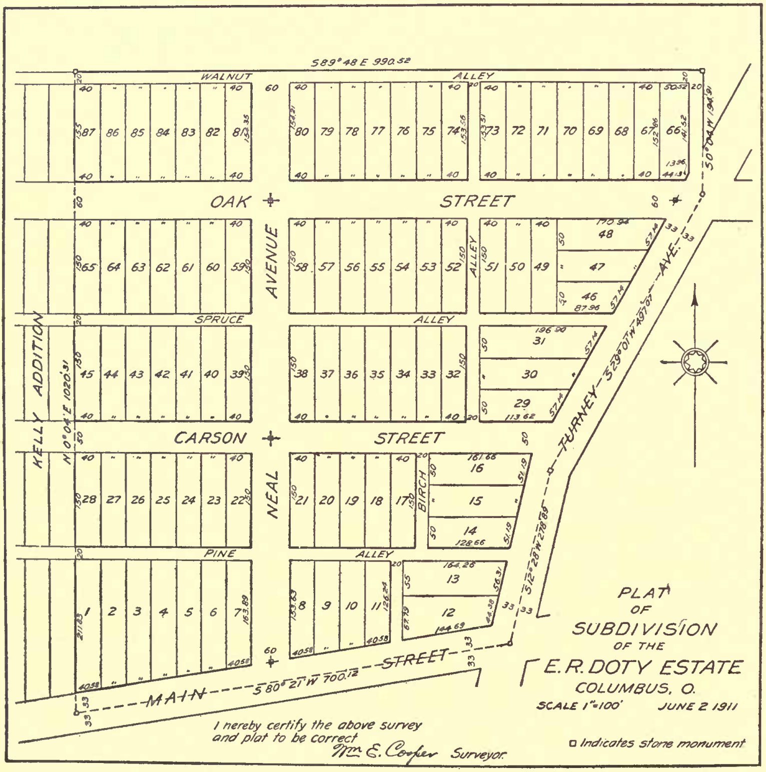


Fig. 407.—A city subdivision.

but care must be taken not to overdo the ornamentation. These drawings are usually finished as blue prints. Fig. 408 is an example showing an acceptable style of execution and finish.

When required for reproduction to small size for illustrative purposes a rendering such as shown in Fig. 409 is sometimes effective.

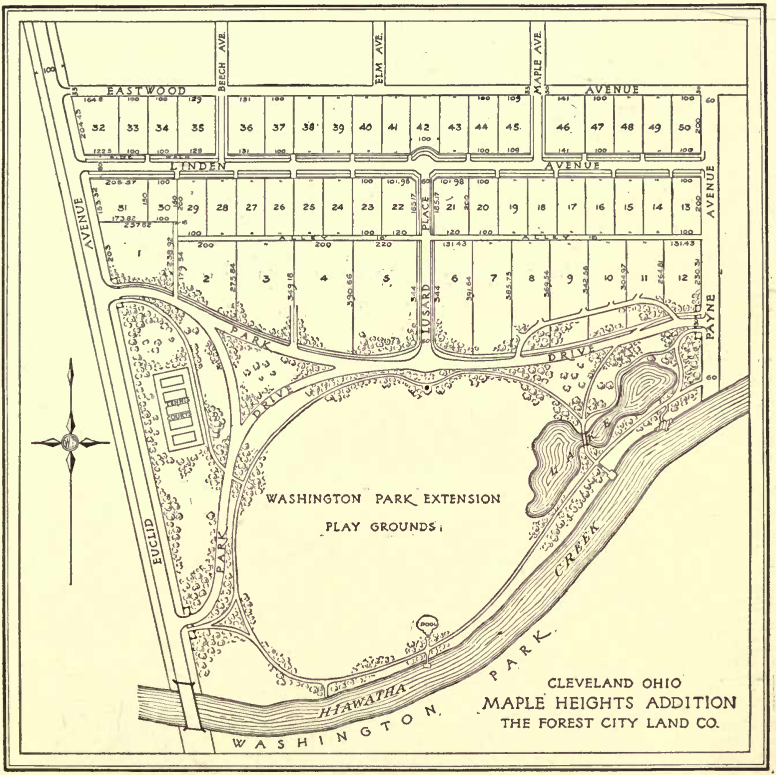


FIG. 408.—A real estate display map.

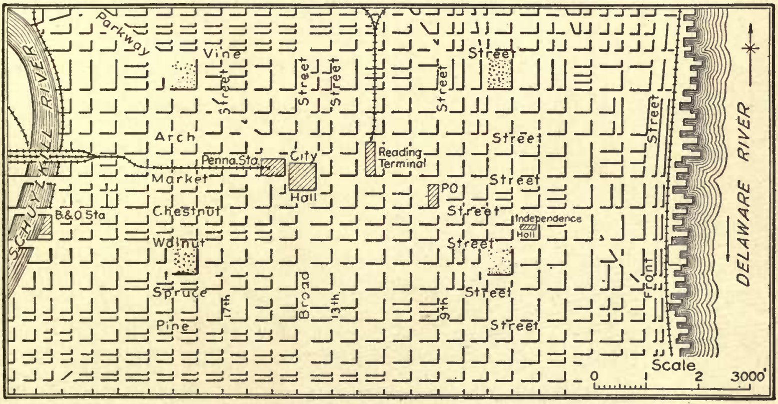


FIG. 409.—A shade line map.

City Plats.

Under this head is included chiefly maps or plats drawn from subdivision plats or other sources for the record of city improvements These plats are used for the record of a variety of information, such as, for example, the location of sewers, water mains, street railways, and street improvements. One valuable use is

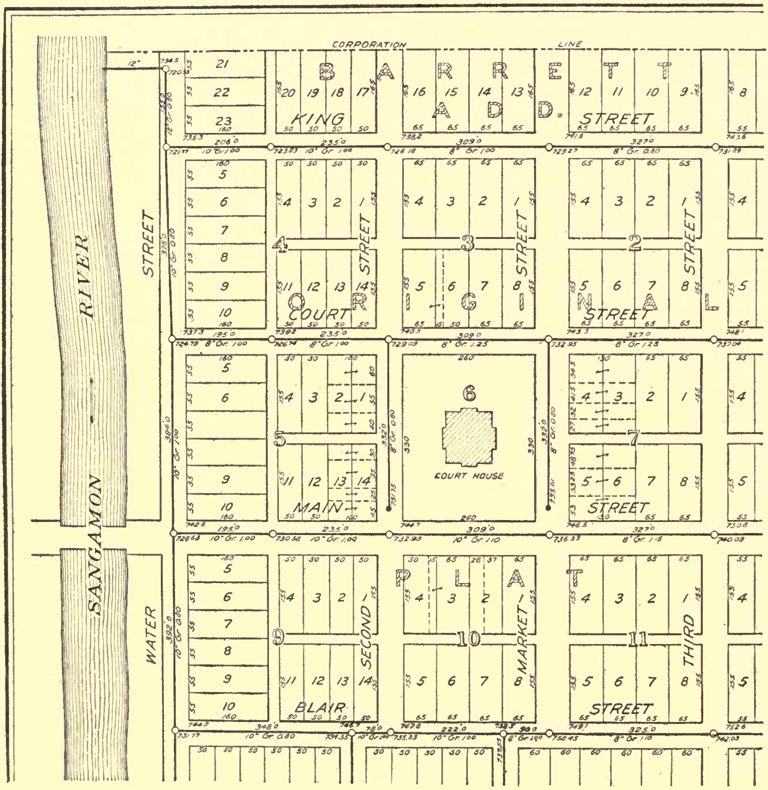


FIG. 410.—A sewer map.

in the levying of assessments for street paving, sewers, etc. As they are made for a definite purpose they should not contain unnecessary information, and hence will not include all the details as to sizes of lots, location of monuments, etc., which are given on subdivision plats.

They are usually made on mounted paper and should be to a scale large enough to show clearly the features required, 100′ and 200′ to the inch are frequent scales, and as large as 50′ is sometimes used. For smaller cities the entire area may be covered by one map; in larger cities the maps are made in convenient sections so as to be filed readily.

A study of Fig. 410, a sewer map, will show the general treatment of such plats. The appearance of the drawing is improved by adding shade lines on the lower and right hand side of the blocks, *i.e.*, treating the streets and water features as depressions.

A few of the more important public buildings are shown, to facilitate reading. The various wards, subdivisions or districts may be shown by large outline letters or numerals as illustrated in the figure.

Topographical Drawing.

As before defined, a complete topographical map would contain:

(1) The imaginary lines indicating the divisions of authority or ownership.

(2) The geographical position of both the natural features and the works of man. They may also include information in regard to the vegetation.

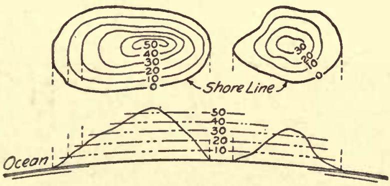


FIG. 411.

(3) The relief, or indication of the relative elevations and depressions.

The relief, which is the third dimension, is represented in general either by contours or by hill shading.

A contour is a line on the surface of the ground which at every point passes through the same elevation, thus the shore line of a body of water represents a contour. If the water should rise one foot the new shore line would be another contour, with one foot "contour interval." A series of contours may thus be illustrated approximately by Fig. 411.

Fig. 412 is a perspective view of a tract of land. Fig. 413 is a contour map of this area, and Fig. 414 is the same surface shown with hill shading by hachures. Contours are drawn as fine, full lines, with every fifth one of heavier weight, and the elevations in

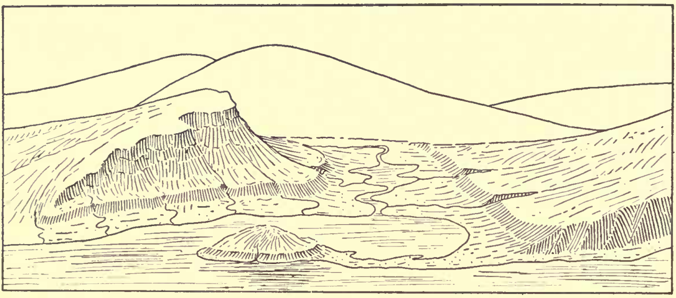


FIG. 412.

feet marked on them at intervals, usually with the sea level as datum. They may be drawn with a swivel pen, Fig. 26, or with a fine pen such as Gillott's 303. On paper drawings they are usually made in brown.

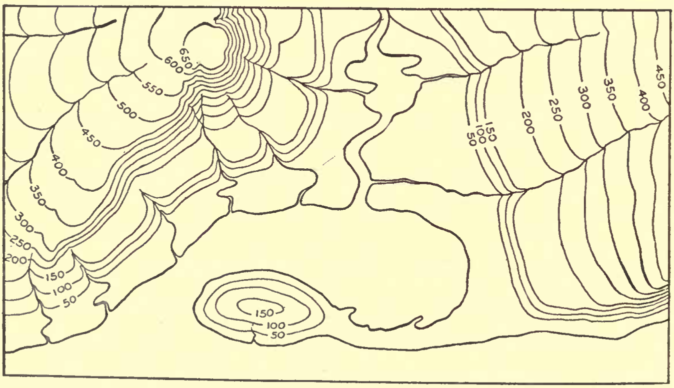


FIG. 413.

The showing of relief by means of hill shading gives a pleasing effect but is very difficult of execution, does not give exact elevations and would not be applied on maps to be used for engineering purposes. They may sometimes be used to advantage in reconnoissance maps, or in small scale maps for illustration. There are several systems, of which hachuring is the commonest. Fig. 415 illustrates the method of execution. The contours are sketched lightly in pencil and the hachures drawn perpendicular

Fig. 414.

to them, starting at the summit and making heavier strokes for steeper slopes. The rows of strokes should touch the pencil line, to avoid white streaks along the contours.

Fig. 416 is a topographic map of the site of a proposed filtra-

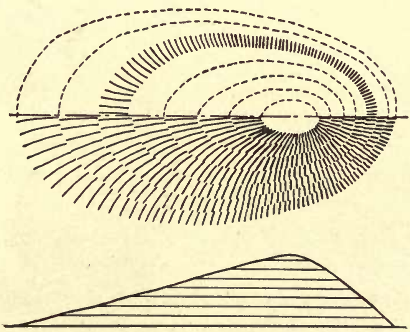


Fig. 415.

tion plant, and illustrates the use of the contour map as the necessary preliminary drawing in engineering projects. Often on the same drawing there is shown, by lines of different character, both the existing contours and the required finished grades.

Water Lining.

On topographic maps made for display or reproduction the water features are usually finished by water-lining," running a system of fine lines parallel to the shore lines, either in black or in blue (it must be remembered that blue will not photograph for reproduction nor print from a tracing). Poor water-lining will ruin the appearance of an otherwise well executed map, and it

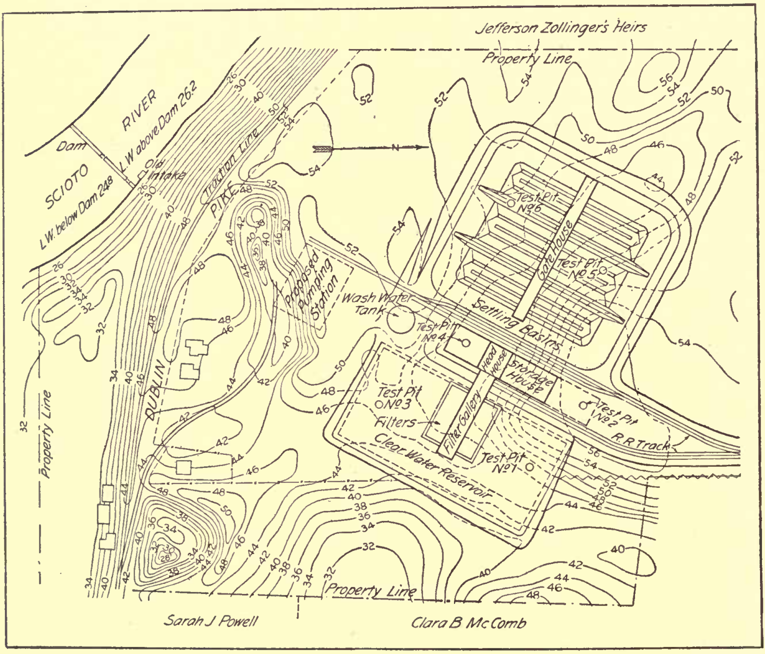


FIG. 416.—Contour map for engineering project.

is better to omit it rather than do it hastily or carelessly. The shore line is drawn first, and the water-lining done with a fine mapping pen, as Gillott's 170 or 290, always drawing toward the body and having the preceding line to the left. The first line should follow the shore line very closely, and the distances between the succeeding lines gradually increased and the irregularities lessened. Sometimes the weight of lines is graded as well as the intervals but this is a very difficult operation and is not necessary for the effect.

A common mistake is to make the lines excessively wavy or rippled.

In water-lining a stream of varying width, the lines are not to be crowded so as to be carried through the narrow portions, but corresponding lines should be brought together in the middle of the stream as illustrated in Fig. 417. Care should be taken to avoid any spots of sudden increase or decrease in spacing.

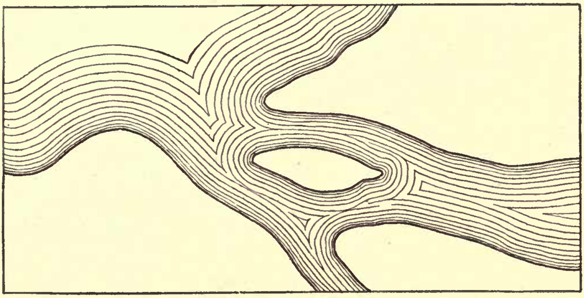


FIG. 417.—Water lining.

Topographic Symbols.

The various symbols used in topographic drawing may be grouped under four heads:

(1) Culture, or the works of man.

(2) Relief—relative elevations and depressions.

(3) Water features.

(4) Vegetation.

When color is used the culture is done in black, the relief in brown, the water features in blue, and the vegetation in black or green.

These symbols, used to represent characteristics on the earth's surface, are made when possible to resemble somewhat the features or object represented as it would appear either in plan or elevation. We cannot attempt to give symbols for all the features that might occur in a map, indeed one may have to invent symbols for some particular locality.

Fig. 418 illustrates a few of the conventional symbols used for cultures or the works of man, and no suggestion is needed as to the method of their execution. When the scale used is large, houses, bridges, roads and even tree trunks can be plotted so

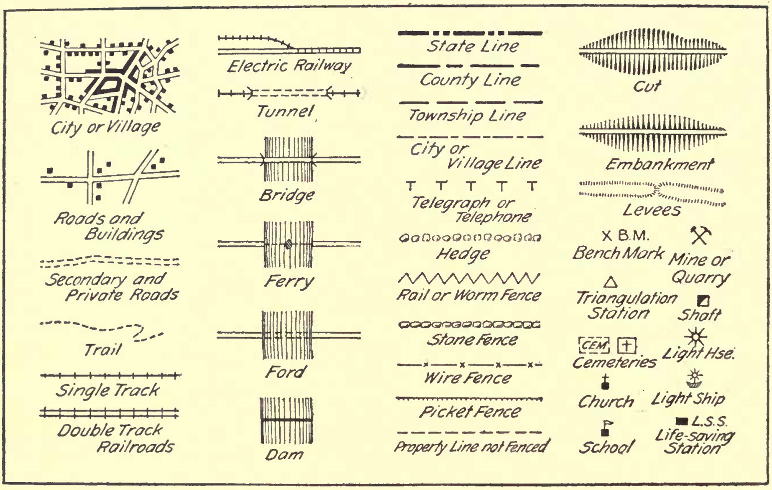


FIG. 418.—Culture.

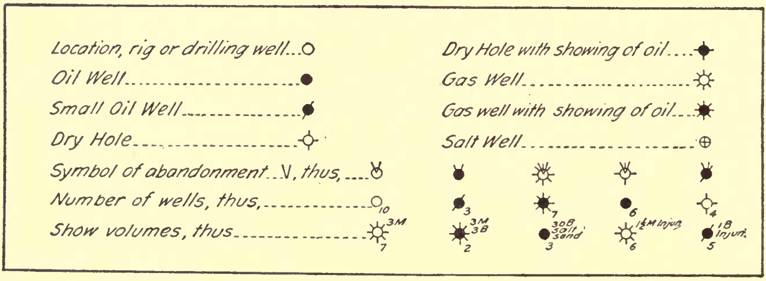


FIG. 419.—Oil and gas symbols.

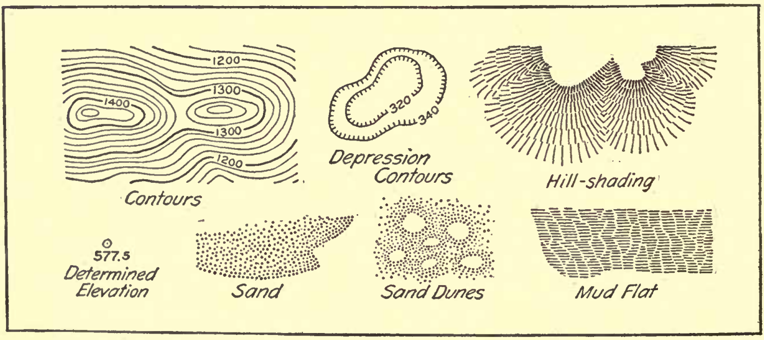


FIG. 420.—Relief.

that their principal dimensions can be scaled. A small scale map can give by its symbols only the relative locations.

Fig. 419 gives the standard symbols used in the development of oil and gas fields.

Fig. 420 contains symbols used to show relief.

Water features are illustrated in Fig. 421.

In Fig. 422 is shown some of the commoner symbols for vegetation and cultivation.

Draftsmen should keep in mind the purpose of the map, and the relative importance of features should be in some measure indicated by their prominence or strength, gained principally

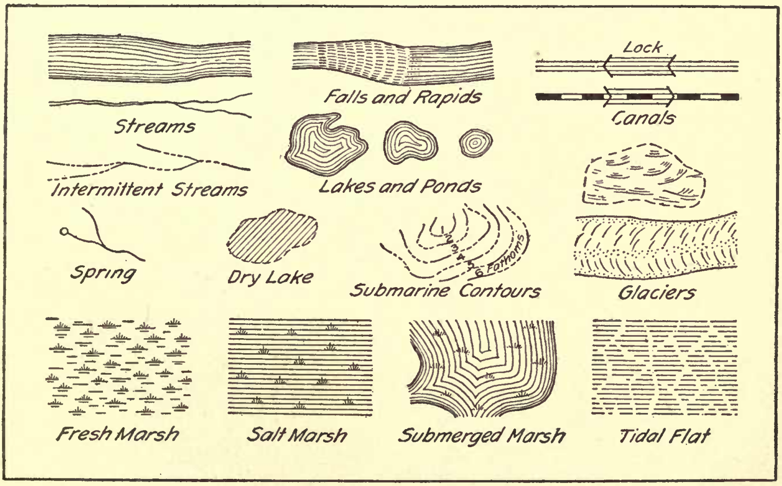


FIG. 421.—Water features.

by the amount of ink used. For instance, in a map made for military maneuvering a cornfield might be an important feature, or in maps made to show the location of special features, such as fire hydrants, etc., these objects would be indicated very plainly. This principle calls for some originality to meet varying cases.

A common fault of the beginner is to make symbols too large. The symbols for grass, shown under "meadow," Fig. 422, if not made and spaced correctly will spoil the entire map. This symbol is composed of from five to seven short strokes radiating from a common center and starting along a horizontal line, as shown in the enlarged form, each tuft beginning and ending with a mere dot. Always place the tufts with the bottom parallel to the border and distribute them uniformly over the space, but not in rows. A few incomplete tufts, or rows of dots improve the appearance. Grass tufts should never be as heavy as tree symbols.

In drawing the symbol for deciduous trees the sequence of strokes shown should be followed.

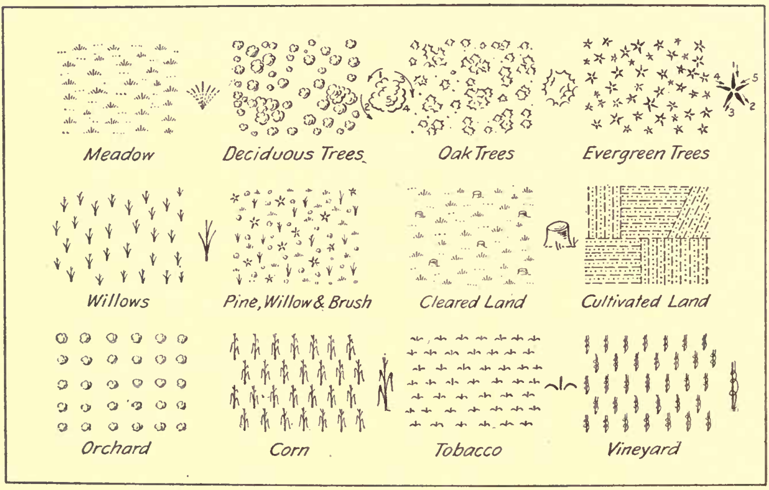


FIG. 422.—Vegetation.

The topographic map, Fig. 423, is given to illustrate the general execution and placing of symbols.

Fig. 424 is a type of map made by landscape architects in the study of improvements for parks, additions, and estates. Shadows are often employed on these maps to show the comparative heights of tall trees, low trees, and shrubs.

Lettering.

The style of lettering on a topographic map will of course depend upon the purpose for which the map is made. If for construction purposes, such as a contour map for the study of municipal problems, street grades, plants, or railroads, the single-stroke gothic and Reinhardt is to be preferred. For a finished map vertical Roman letters for land features, and inclined

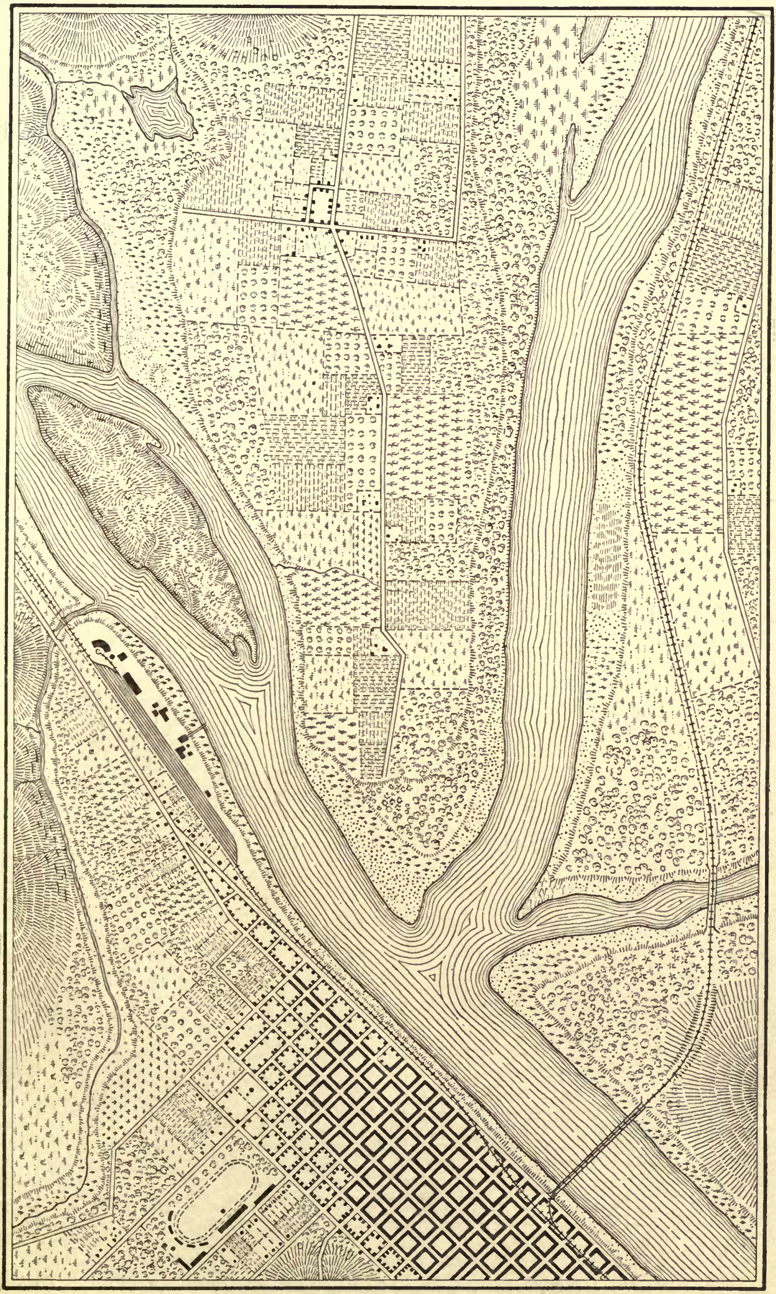


FIG. 423.—A Topographic Map.

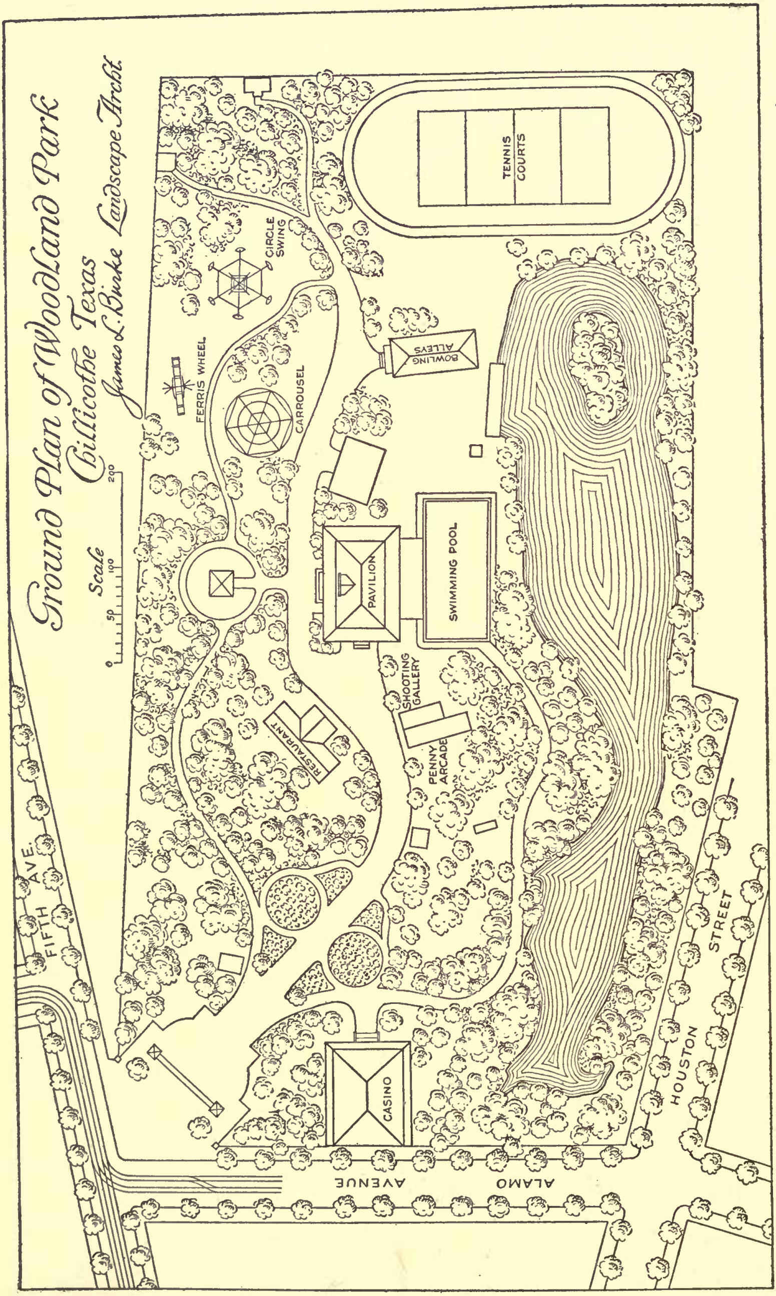


Fig. 424.—Landscape architect's map.

Roman and stump letters for water features should be used. The scale should always be drawn as well as stated.

The well known maps of the Coast Survey and Geological Survey are good examples of this kind of map. The quadrangle sheets issued by the topographic branch of the U. S. Geological Survey are excellent examples and so easily available that every draftsman should be familiar with them. These sheets represent 15 min. of latitude and 15 min. of longitude, and the entire United States is being mapped by the department. In 1911 about 81 per cent. of New York state, 50% of Pennsylvania, and 67% of Ohio, and other states in somewhat the same percentages are already completed. These maps may be secured for 5 cents each (not stamps) by addressing *The Director, U. S. Geological Survey, Washington, D. C.*, from whom information as to the completion of any particular locality or the progress in any state may be had. The scale of these maps is approximately 1 inch to the mile. Some territory in the West has been mapped to 1/2 inch to the mile. On the back of each sheet will be found a code of the conventional symbols used by the department.

Profiles.

Perhaps no kind of drawing is used more by civil engineers than the ordinary profile, which is simply a vertical section taken along a given line either straight or curved. Such drawings are indispensable in problems of railroad construction, highway and street improvements, sewer construction, and many other problems where a study of the surface of the ground is required. Very frequently engineers other than civil engineers are called upon to make these drawings. Several different types of profile and cross-section paper are in use and may be found in the catalogues of the various firms dealing in drawing materials. One type of profile paper in common use is known as "Plate A" in which there are four divisions to the inch horizontally and twenty to the inch vertically. Other divisions which are used are 4×30 to the inch and 5×25 to the inch. At intervals both horizontally and vertically somewhat heavier lines are made in order to facilitate reading.

Horizontal distances are plotted as abscisses and elevations as ordinates. The vertical distances representing elevations, being plotted to larger scale, a vertical exaggeration is obtained which is very useful in studying the profile for the establishing of grades. The vertical exaggeration is sometimes confusing to the layman or inexperienced engineer, but ordinarily a profile will fail in the purpose for which it was intended if the horizontal and vertical scale are the same. Again the profile unless so

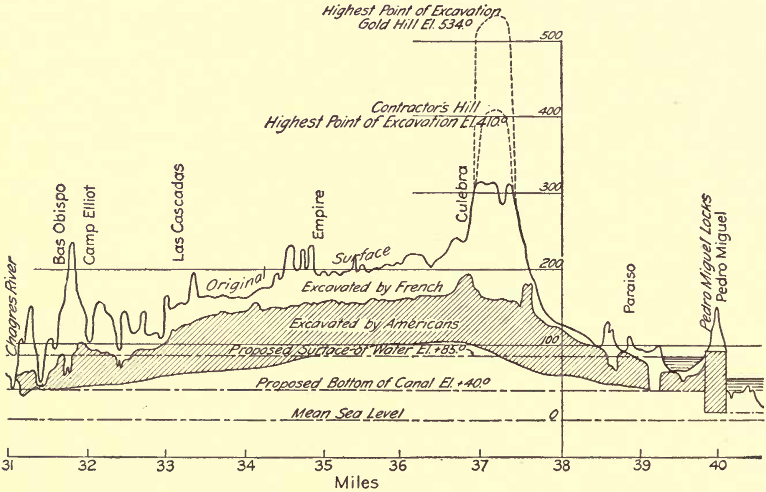


FIG. 425.—Profile. (Vert. scale 50 times hor.)

distorted would be a very long and unwieldy affair, if not entirely impossible to make. The difference between profiles with and without vertical exaggeration is shown in Figs. 425 and 426. Fig. 427 is a profile together with the alignment which is drawn

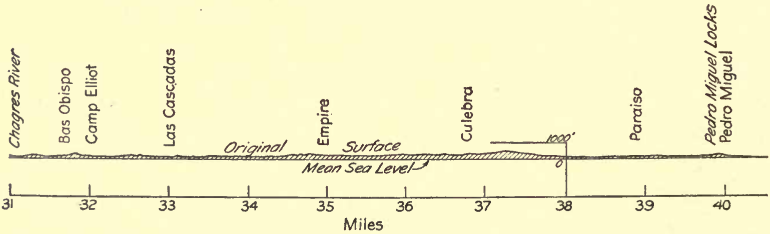


FIG. 426.—Profile. (Vert. and hor. scales equal.)

just below the profile proper. This figure represents a common method employed by draftsmen in railroad offices. Attention is called to the method of straightening out the alignment. Such a method is also used on surveys for improvement of highways and the like.

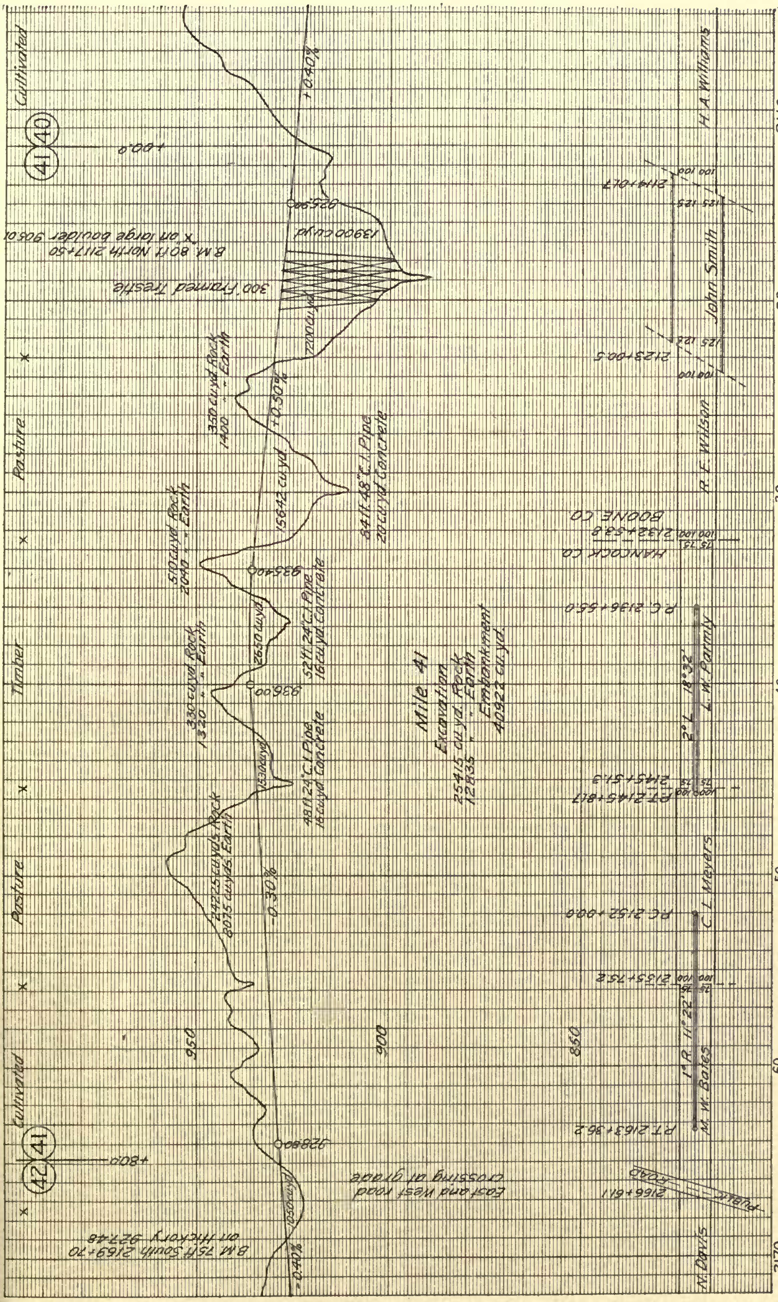


FIG. 427.—Standard profile for railroad construction.

CHAPTER XIII.

Duplication and Drawing for Reproduction.

As has been stated, working drawings or any drawings which are to be duplicated are traced. Sometimes drawings of a temporary character are, for economy, traced on white tracing paper, but tracing cloth is more transparent, much more durable, prints better, and is easier to work on.

Drawings intended for blue printing are sometimes penciled and inked on bond or ledger paper. A print from these papers requires more exposure and has a mottled appearance, showing plainly the texture and watermarks.

Tracing cloth is a fine thread fabric, sized and transparentized with a starch preparation. The three brands Excelsior, Imperial, and Kohinoor are recommended. The smooth side is considered by the makers as the right side, but most draftsmen prefer to work on the dull side, principally because it will take a pencil mark. The cloth should be tacked down smoothly over the pencil drawing and its selvage torn off. It should then be dusted with chalk or prepared pounce and rubbed off with a cloth, to remove traces of grease which sometimes prevents the flow of ink (a blackboard eraser serves very well for this purpose).

To insure good printing the ink should be perfectly black, and the outline should be made with a bolder line than would be used on paper, as the contrast of a white line on the blue ground is not so strong as the black line on a white ground. Red ink should not be used unless it is desired to have some lines very inconspicuous. Blue ink will not print. Sometimes, in maps, diagrams, etc., to avoid confusion of lines, it is desired to use colored inks on the tracing; if so a little Chinese white added will render them opaque enough to print.

Sometimes, instead of section lining, sections are indicated by rubbing a pencil tint over the surface on the dull side, or by putting a wash of color on the tracing either on the smooth side or on the dull side. These tints will print in lighter blue than the background.

Ink lines may be removed from tracing cloth by rubbing with a pencil eraser. A triangle should be slipped under the tracing to give a harder surface. The rubbed surface should afterward be burnished with an ivory or bone burnisher, or with a piece of talc (tailor's chalk) or, in the absence of other means, with the thumb nail. In tracing a part that has been section lined, a piece of white paper should be slipped under the cloth and the section lining done without reference to the drawing underneath.

For an unimportant piece of work it is possible to make a freehand tracing from an accurate pencil drawing in perhaps one-half the time required for a mechanical drawing.

Tracing cloth is very sensitive to atmospheric changes, often expanding over night so as to require restretching. If the complete tracing cannot be finished during the day some views should be finished, and no figure left with only part of its lines traced.

Water will ruin a tracing, and moist hands or arms should not come in contact with the cloth. The habit should be formed of keeping the hands off drawings. It is a good plan, in both drawing and tracing on large sheets, to cut a mask of drawing paper to cover all but the view being worked on. Unfinished drawings should always be covered over night.

Tracings may be cleaned of pencil marks and dirt by rubbing over with a rag or waste dipped in benzine or gasolene.

The starch may be washed from scrap tracing cloth to make penwipers or cloths.

The tracing is a "master drawing" and should never be allowed to be taken out of the office, but prints may be made from it by one of the processes described below. Any number of prints may be taken from one tracing.

Blue Printing.

The simplest of the printing processes is blue printing, made by exposing a piece of sensitized paper in contact with the tracing to sunlight or electric light in a printing frame made for the purpose. The blue print paper is a white paper free from sulphites, coated with a solution of citrate of iron and ammonia, and ferricyanide of potassium. On exposure to the light a chemical action takes place, which when fixed by washing in water gives a strong blue color. The parts protected from the light by the black lines of the tracing wash out, leaving the white paper. Blue-print paper is usually bought ready sensitized, and may be had in different weights and different degrees of rapidity. When fresh it is of a yellowish green color, and an unexposed piece should wash out perfectly white. With age or exposure to light or air, it turns to a darker gray-blue color, and spoils altogether in a comparatively short time. In some emergency, it may be necessary to prepare blue-print paper. The following formula will give a paper requiring about three minutes' exposure in bright sun-light.

(1) Citrate of iron and ammonia (brown scales) 2 oz., water 8 oz.

(2) Red prussiate of potash 1 1/2 oz., water 8 oz.

Keep in separate bottles away from the light.

To prepare paper take equal parts of (1) and (2) and apply evenly to the paper with a sponge or camel's-hair brush, by subdued light.

To make a blue print.

Lay the tracing in the frame with the inked side toward the glass, and place the paper on it with its sensitized surface against the tracing. Lock up in the frame so there is a perfect contact

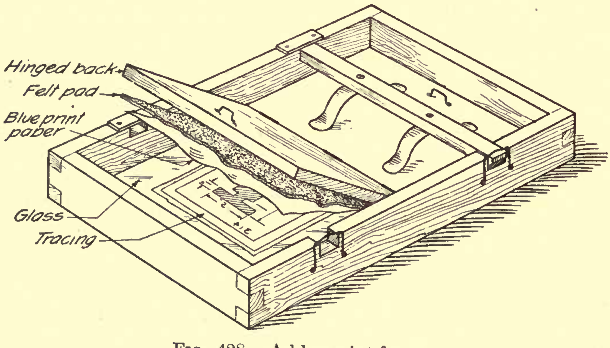


FIG. 428.—A blue print frame.

between paper and cloth. See that no corners are turned under. Expose to the sunlight or electric light. If a frame having a hinged back is used, Fig. 428, one side may be opened for examination. When the paper is taken from the frame it will be a bluish gray color with the heavier lines lighter than the background, the lighter lines perhaps not being distinguishable. Put the print for about five minutes in a bath of running water, taking care that air bubbles do not collect on the surface, and hang up to dry. An overexposed print may often be saved by prolonged washing. The blue color may be intensified and the whites cleared by dipping the print for a moment into a bath containing a solution of potassium bichromate (1 to 2 oz. of crystals to a gallon of water), and rinsing thoroughly. This treatment will bring back a hopelessly "burned" print.

To be independent of the weather, most concerns use electric printing machines, either cylindrical, in which a lamp is lowered automatically inside a glass cylinder about which the tracing and paper are held, or continuous, in which the tracing and paper are fed through rolls, and in some machines, printed, washed and dried in one operation.

Prints too large for a frame may be made in sections and pasted together.

In an emergency it is possible to make a fair print by holding tracing and paper to the sunlight against a window pane.

A clear blue print may be made from a typewritten sheet which has been written with a sheet of carbon paper back of it, so that it is printed on both sides.

Van Dyke paper is a thin sensitized paper which turns dark brown on exposure and fixing, which is done by first washing in water, then in a bath of hyposulphite of soda, and washing again thoroughly. A reversed negative of a tracing may be made on it by exposing with the inked side of the tracing next to the sensitized side of the paper. This negative, if printed on blue-print paper will give a blue-line print with white background.

The Van Dyke negative may be "transparentized" so as to print in one-half to one-third the time, by a solution sold by the dealers, or by a solution of paraffin cut in benzine.

A direct black paper is made by the Carlton Supply Co., Brooklyn, N. Y., which is printed and washed the same as a blue print and gives permanent black lines on white ground.

White ground prints have the advantage that additions or notes may be made in ink or pencil, and that tints may be added.

Changes are made on blue prints by writing or drawing with any alkaline solution, such as of soda or potash, which bleaches the blue. A little gum arabic will prevent spreading. A tint may be given by adding a few drops of red or other colored ink to the solution. Chinese white is sometimes used for white-line changes on a blue print.

A blue print may be made from a drawing made in pencil or ink on bond paper or tracing paper, but with thick drawing paper the light will get under the lines and destroy the sharpness. A print may be made from Bristol or other heavy white paper by turning it with the ink side against the paper, thereby reversing the print, or by making a Van Dyke negative, with a long exposure; or it may be soaked in benzine and printed while wet. The benzine will evaporate and leave no trace.

A blue-line print may be taken from a blue print by fading the blue of the first print in weak ammonia water, washing thoroughly, then turning it red in a weak solution of tannic acid, and washing again. Transparentizing at this stage will assist.

In printing a number of small tracings they may be fastened together at their edges with gummed stickers and handled as a single sheet.

Any white paper may be rendered sufficiently translucent to give a good blue print, with the "transparentizing solutions" mentioned before, and a machine called the "mechanigraph" is now on the market which does this commercially, enabling drawings to be made on white paper in pencil, from which finished prints can be made without inking or tracing.

The methods of the hectograph or gelatine pad, neostyle, mimeograph, etc., often used for duplicating small drawings, are too well known to need description here.

Large drawings or drawings in sets are often photographed to reduced size and blue prints or other prints made from the negatives giving convenient prints for reference.

Drawing for Reproduction.

By this term is meant the preparation of drawings for reproduction by one of the photo-mechanical processes used for making plates, or "cuts," as they are often called, for printing purposes. Such drawings will be required in the preparation of illustrations for books and periodicals, for catalogues or other advertising, and incidentally for patent office drawings, which are reproduced by photo-lithography.

Line drawings are usually reproduced by the process known as zinc etching, in which the drawing is photographed on a process plate, generally with some reduction, the negative film reversed and printed so as to give a positive on a sensitized zinc plate (when a particularly fine result is desired, a copper plate is used)

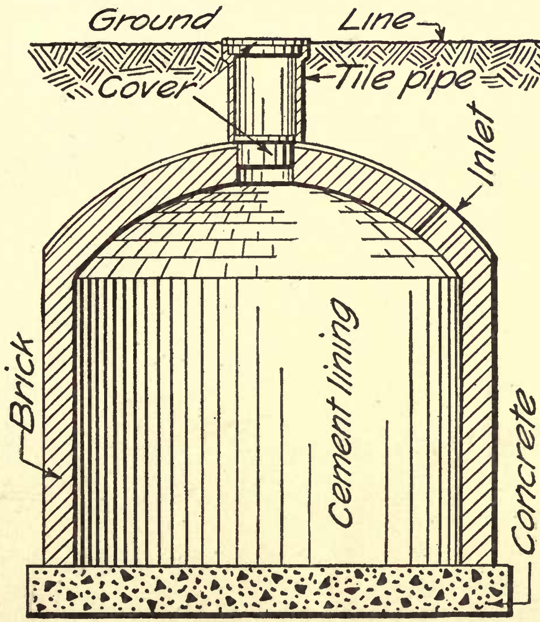


FIG. 429.—Drawing for one-half reduction.

FIG. 430.

which is etched with acid, leaving the lines in relief and giving, when mounted type-high on a wood base, a block which can be printed along with type in an ordinary printing press.

Drawings for zinc etching should be made on smooth white paper or tracing cloth in black drawing ink and preferably larger than the required reproduction.

If it is desired to preserve the hand-drawn character of the

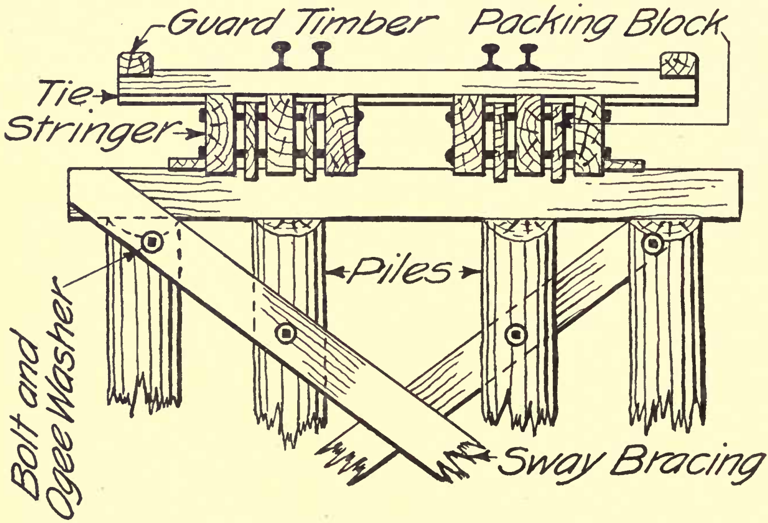


Fig. 431.—Drawing for "two-thirds" reduction.

original, the reduction should be slight; but if a very smooth effect is wanted, the drawing may be as much as 3 or 4 times as large as the cut. The best general size is one and one-half times linear. Fig. 429 illustrates the appearance of an original

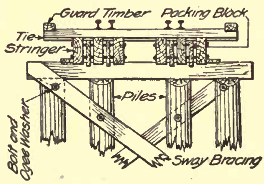


Fig. 432.

drawing and Fig. 430 the same drawing reduced one-half. Fig. 431 is another original which has been reduced two-thirds, Fig. 432. The coarse appearance of these originals and the open shading should be noticed.

A reducing glass, a concave lens mounted like a reading glass is sometimes used to aid in judging the appearance of a drawing on reduction. If lines are drawn too close together the space between them will choke in the reproduction and mar the effect.

One very convenient thing not permissible in other work may be done on drawings for reproduction—any irregularities may be corrected by simply painting out with Chinese white. If it is desired to shift a figure after it has been inked it may be cut out and pasted on in the required position. The edges thus left will not trouble the engraver, as they will be tooled out when the etching is finished.

Wash drawings and photographs are reproduced in a similar way on copper by what is known as the half-tone process in which the negative is made through a ruled "screen" in front of the plate, which breaks up the tints into a series of dots of varying size. Screens of different fineness are used for different kinds of paper, from the coarse screen newspaper half-tone of 80 to 100 lines to the inch, the ordinary commercial and magazine half-tone of 133 lines, to the fine 150 and 175 line half-tones for printing on very smooth coated paper.

Photographic prints for reproduction are often retouched and worked over, shadows being strengthened with water color, high-lights accented with Chinese white, and details brought out that would otherwise be lost. In catalogue illustration of machinery, etc., objectionable backgrounds or other features can be removed entirely. Commercial retouchers use the air-brush as an aid in this kind of work, spraying on color with it very rapidly and smoothly and securing results not possible in hand-work.

Half tones cost from ten to fifteen cents per sq. in. with a minimum price of $1.00, and zinc etching from five to seven cents per sq. in. with a minimum of sixty cents.

Line illustrations are sometimes made by the "wax process" in which a blackened copper plate is covered with a very thin film of wax, on which a drawing may be photographed and its outline scratched through the wax by hand with different sized gravers. The lettering is set up in type and pressed into the wax; more wax is then piled up in the wider spaces between the lines and an electrotype taken. Drawings for this process need not be specially prepared, as the work may be done even from a pencil sketch or blue print. Wax plates print very clean and sharp and the type-lettering gives them a finished appearance, but they lack the character of a drawing, are more expensive than zinc etching and often show mistakes due to the lack of familiarity of the engraver with the subject. Fig. 433 shows the characteristic appearance of a wax plate.

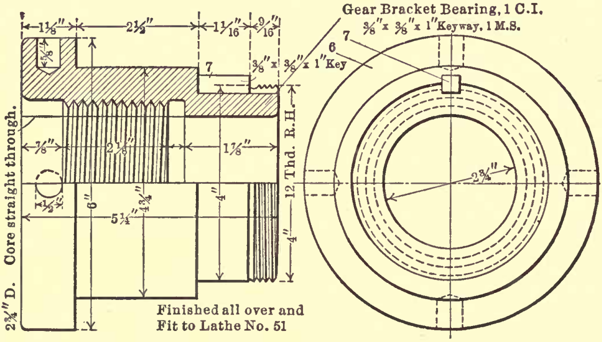


FIG. 433.—A wax plate.

Maps and large drawings are usually reproduced by lithography, in which the drawing is either photographed or engraved on a lithographic stone, and transferred from this either to another stone from which it is printed or in the offset process to a thin sheet of zinc which is wrapped around a cylinder, and prints to a rubber blanket which in turn prints on the paper.

CHAPTER XIV.

NOTES ON COMMERCIAL PRACTICE.

Under this heading there is included a number of suggestions and items of miscellaneous information for student and draftsman.

To Sharpen a Pen.

Pens that are in constant use require frequent sharpening and every draftsman should be able to keep his own pens in fine condition. The points of a ruling pen should have an oval or elliptical shape as (a) Fig. 434, with the nibs exactly the same length. (b) is a worn pen and (c) (d) and (e) incorrect shapes

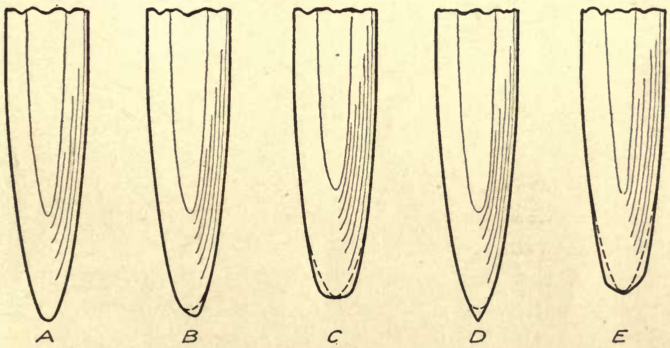


FIG. 434.—Corrected ruling pen points.

sometimes found. The best stone to use is a hard Arkansas knife piece or knife edge. It is best to soak a new stone in oil for several days before using. The ordinary carpenter's oil stone is too coarse to be used for instruments.

The nibs must first be brought to the correct shape as (a) and as indicated on the dotted lines of (b), (c) and (d). This is done by screwing the nibs together until they touch and, holding the pen as in drawing a line, drawing it back and forth on the stone, starting the stroke with the handle at perhaps 30 degrees with the stone, and swinging it up past the perpendicular as the line across the stone progresses. This will bring the nibs to exactly equal shape and length, leaving them very dull. They should then be opened slightly and each blade sharpened in turn until the bright spot on the end has just disappeared, holding the pen as in Fig. 435 at a small angle with the stone and rubbing it back and forth with a slight oscillating or rocking motion to conform to the shape of the blade. The pen should be examined frequently and the operation stopped just when the reflecting spot has vanished. A pocket magnifying glass may be of aid in examining the points. The blades should not be sharp enough to cut the paper when tested by drawing a line, without ink, across it. If over-sharpened the blades should

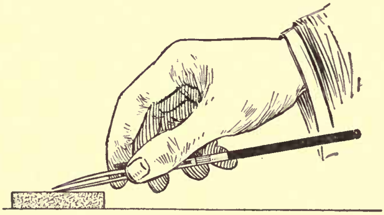


Fig. 435.

again be brought to touch and a line drawn very lightly across the stone as in the first operation. When tested with ink the pen should be capable of drawing clean sharp lines down to the finest hair line. If these finest lines are ragged or broken the pen is not perfectly sharpened. It should not be necessary to touch the inside of the blades unless a bur has been formed, which might occur with very soft metal or by using too coarse a stone. In such cases the blades should be opened wide and the bur removed by a very light touch, with the entire inner surface of the blade in contact with the stone, which of course must be sufficiently thin to be inserted between the blades. The beginner had best practise by sharpening several old pens before attempting to sharpen a good instrument. After using, the stone should be wiped clean and a drop of oil rubbed over it to prevent hardening and glazing.

To Make a Lettering Pen.*

Lettering should never be done with the ruling pen, but some draftsmen make a lettering pen for coarse single-stroke letters,

* Described by Prof. C. L. Adams.

out of an old ruling pen by first rubbing the point very blunt, then grinding the blades together to a conical shape, and finally shaping a ball end on the blunted point. This pen will make a line somewhat similar to that made by the Payzant and Shepard pens. Its handle should be plainly cut or marked to distinguish it from a ruling pen.

Line Shading.

Line shading, the rendering of the effect of light and shade by ruled lines, was referred to in Chapter VI as "an accomplishment not usual among ordinary draftsmen." The reason for this is that it is not used at all on working drawings and the draftsman engaged in that work does not have occasion to apply it. It is used, however, on display drawings, illustrations, patent office drawings, and the like, and is worthy of study if one is interested in this class of finished work.

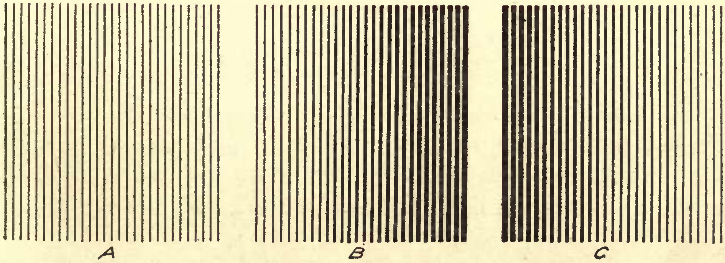


FIG. 436.—Flat and graded tints.

To execute line shading rapidly and effectively requires continued practice and some artistic ability, and, as much as anything else, good judgment in knowing when to stop. Often the simple shading of a shaft or other round member will add greatly to the effectiveness of a drawing, and may even save making another view, or a few lines of "surface shading" on a flat surface will show its position and character. The pen must be in perfect condition, with its screw working very freely.

Fig. 436 shows three preliminary exercises in flat and graded tints in which the pitch or distance from center to center of lines is equal. In wide graded tints as (b) and (c) the setting of the pen is not changed for every line, but several lines are drawn, then the pen changed slightly and several more drawn. Fig. 437 is an application, illustrating the rule that *an inclined illuminated surface is lightest nearest the eye and an inclined surface in shade is darkest nearest the eye.*

With the light coming in the conventional direction a cylinder would be illuminated as in Fig. 438. Theoretically the darkest

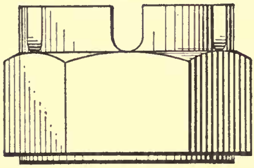


FIG. 437.

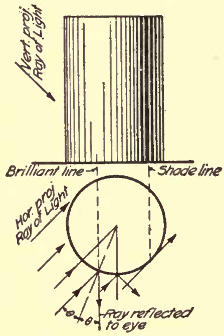


FIG. 438.

line is at the tangent or shade line and the lightest part at the "brilliant line" where the light is reflected directly to the eye. Cylinders shaded according to this theory are the most effective, but often in practice the dark side is carried out to the edge, and in small cylinders the light side is left unshaded.

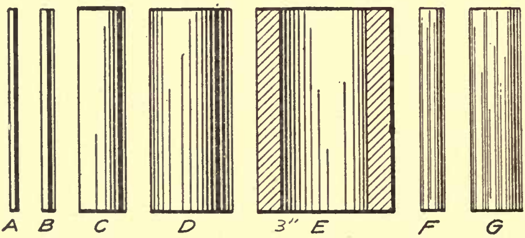


FIG. 439.—Cylinder shading.

Fig. 439 is a row of cylinders of different sizes. The effect of polish is given by leaving several brilliant lines, as might occur if the light came in through several windows.

A conical surface may be shaded by driving a fine needle at the apex and swinging a triangle about it, as in (*A*) Fig. 440.

To avoid a blot at the apex of a complete cone the needle may be driven on the extension of the side as in (*B*), or it may be shaded by parallel lines as in (*C*).

Fig. 441 illustrates several applications of these principles.

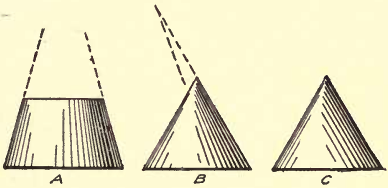


FIG. 440.—Cone shading.

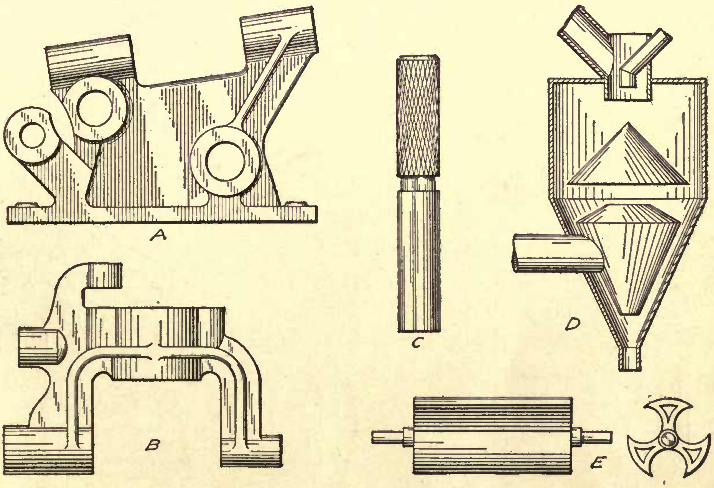


FIG. 441.—Shaded single curved surfaces.

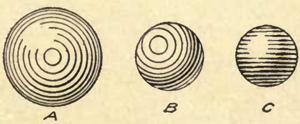


FIG. 442.—Spheres.

It is in the attempt to represent double curved surfaces that the line-shader meets his principal troubles. The brilliant line becomes a brilliant point and the tangent shade line a curve, and to represent the gradation between them by mechanical lines is a difficult proposition.

Fig. 442 shows three methods of shading a sphere. The brilliant point and shade line may be found by revolving the projecting plane of the ray passing through the center, about its

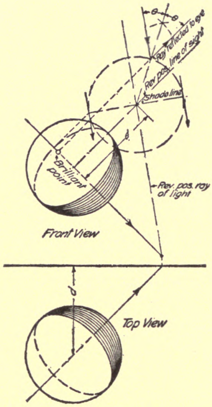


Fig. 443.

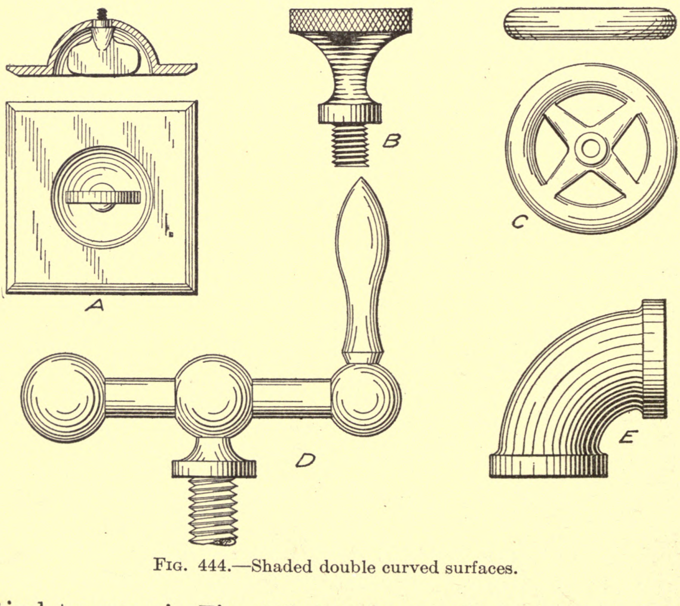


Fig. 444.—Shaded double curved surfaces.

vertical trace as in Fig. 443, but in practice these are usually "guessed in." The first method (a) is the commonest. Concentric circles are drawn from the center, with varying pitch, and shaded on the lower side by springing the point of the compass. In (b) the brilliant point is used as center. In (c), the "wood cut" method, the taper on the horizontal lines is made by starting with the pen out of perpendicular and turning the handle up as the line progresses.

Fig. 444 shows several applications with double curved surfaces of different kinds.

Patent Office Drawings.

In the application for letters patent on an invention or discovery there is required a written description called the specification, and in case of a machine, manufactured article, or device for making it, a drawing, showing every feature of the invention. If it is an improvement, the drawing must show the invention separately, and in another view a part of the old structure with the invention attached. A high standard of execution, and conformity to the rules of the Patent Office must be observed. A pamphlet called the "Rules of Practice," giving full information and rules governing patent office procedure in reference to application for patents may be had gratuitously by addressing the *Commissioner of Patents, Washington, D. C.*

The drawings are made on smooth white paper specified to be of a thickness equal to three-sheet Bristol-board. Two-ply Reynolds board is the best paper for the purpose, as prints may be made from it readily, and it is preferred by the Office. The sheets must be exactly 10 by 15 inches, with a border line one inch from the edges. Sheets with border and lettering printed, as Fig. 445, are sold by the dealers, but are not required to be used.

A space of not less than 1 1/4 inches inside of the top border must be left blank for the printed title added by the Office.

Drawings must be in black ink, and drawn for a reproduction to reduced scale. As many sheets as are necessary may be used. In the case of large views any sheet may be turned on its side so that the heading is at the right and the signatures at the left, but all views on the same sheet must stand in the same direction.

Patent Office drawings are not working drawings. They are descriptive and pictorial rather than structural, hence will have no center lines, no dimension lines nor figured dimensions, no notes nor names of views. The scale chosen should be large enough to show the mechanism without crowding. Unessential details or shapes need not be represented with constructional accuracy, and parts need not be drawn strictly to scale. For example, the section of a thin sheet of metal drawn to scale might be a very thin single line, but it should be drawn with a double line, and section-lined between.

Section lining must not be too fine. One-twentieth of an inch pitch is a good limit. Solid black should not be used excepting to represent insulation or rubber.

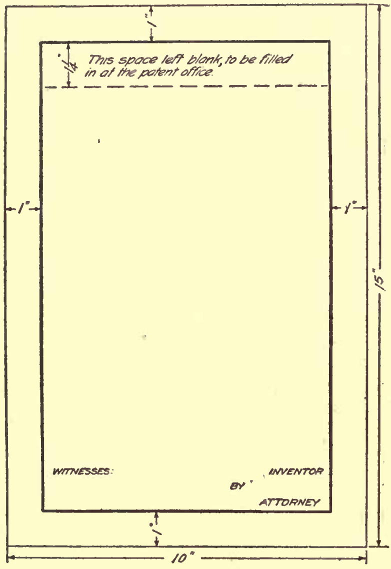


Fig. 445.

Shade lines are always added, except in special cases where they might confuse or obscure instead of aid in the reading.

Surface shading by line shading is used whenever it will add to the legibility, but it should not be thrown in indiscriminately or lavishly simply to please the client.

Gears and toothed wheels must have all their teeth shown, and the same is true of chains, sprockets, etc., but screw threads may be represented by the conventional symbols. The *Rules of Practice* gives a chart of electrical symbols, symbols for colors, etc., which should be followed.

The drawings may be made in orthographic, axonometric, oblique, or perspective. The pictorial system is used extensively, for either all or part of the views. The examiner is of course expert in reading drawings, but the client, and sometimes the attorney, may not be, and the drawing should be clear to them. In checking the drawing for completeness it should be remembered that in case of litigation it may be an important exhibit in the courts.

Only in rare cases is a model of an invention required by the Office.

The views are lettered "Fig. 1," "Fig. 2" etc., and the parts designated by reference numbers though which the invention is described in the specifications. One view, generally "Fig. 1," is made as a comprehensive view that may be used in the Official Gazette as an illustration to accompany the "claims."

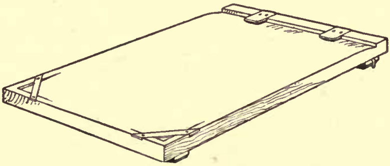


Fig. 446.

The draftsman usually signs the drawing as the first witness. The inventor signs the drawing in the lower right-hand corner. In case an attorney prepares the application and drawing, the attorney writes or letters the name of the inventor, signing his own name underneath as his attorney.

To avoid making tack holes in the paper it should be held to the board by the heads of the thumb tacks only.

Fig. 446 is a clamp drawing board used by some patent draftsmen.

The requirements for drawings for foreign patents vary in different countries, most countries requiring drawings and several tracings of each sheet.

Fig. 447 is an example of a patent office drawing, reduced to 1/2 size.

Stretching Paper and Tinting.

If a drawing is to be tinted the paper should be stretched on the board. First, dampen it thoroughly until limp, either with

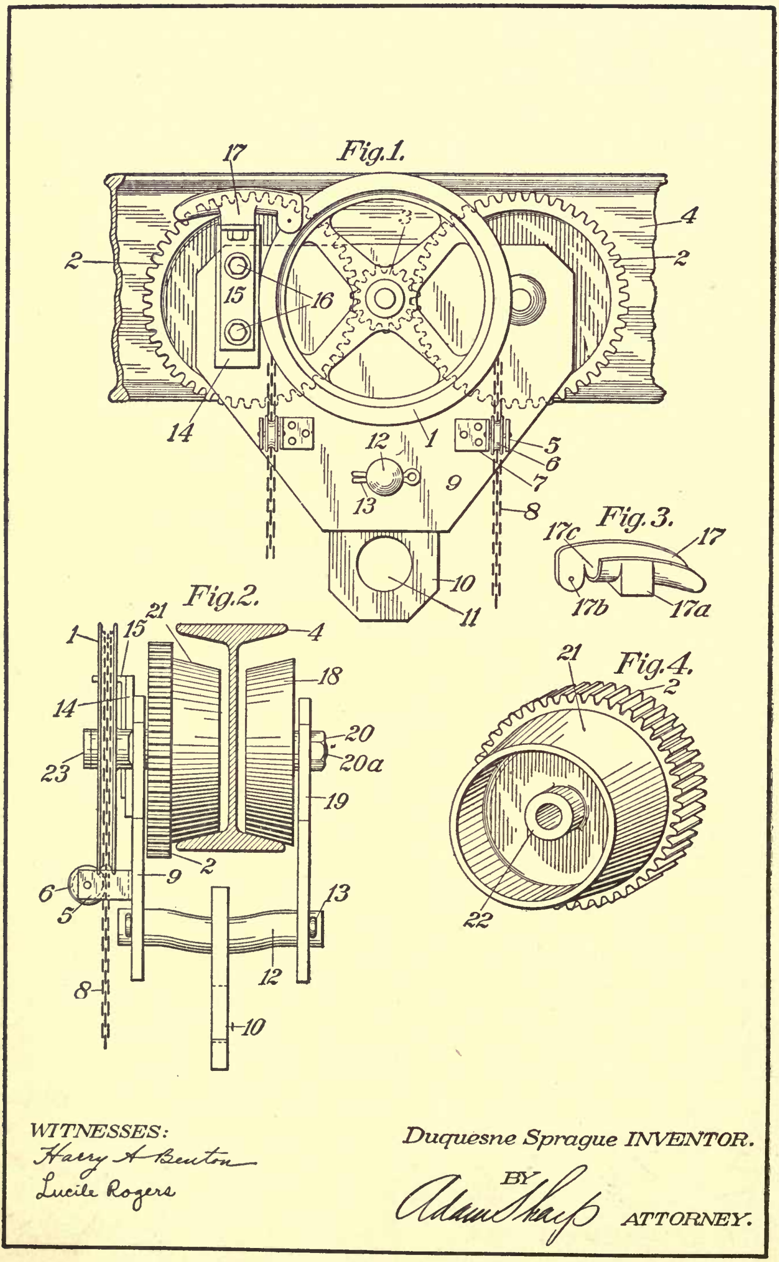


Fig. 447.—A patent office drawing.

a sponge or under the faucet, then lay it on the drawing board face down, take up the excess water from the edges with a blotter, brush glue or paste about one-half inch wide around the edge, turn over and rub the edges down on the board until set, and allow to dry horizontally.

Drawings or maps on which much work is to be done, even though not to be tinted, may be made advantageously on stretched paper; but Bristol or calendered paper should not be stretched.

Tinting is done with washes made with moist water colors. The drawing may be inked (with waterproof ink) either before, or preferably after tinting.

The drawing should be cleaned and the unnecessary pencil marks removed with a very soft rubber, the tint mixed in a saucer and applied with a camel's-hair or sable brush, inclining the board and flowing the color with horizontal strokes, leading the pool of color down over the surface, taking up the surplus at the bottom by wiping the brush out quickly and picking up with it the excess color. Stir the color each time the brush is dipped into the saucer. Tints should be made in light washes, depth of color being obtained if necessary by repeating the wash. To get an even color it is well to go over the surface first with a wash of clear water.

Diluted colored inks may be used for washes instead of water color.

Mounting Tracing Paper.

Tracings are mounted for display, on white mounts, either by "tipping" or "floating." To tip a drawing brush a narrow strip of glue or paste around the under edge, dampen the right side of the drawing by stroking with a sponge very slightly moistened, and stretch the paper gently with the thumbs on opposite edges, working from the middle of the sides toward the corners.

To float a drawing make a *very thin* paste and brush a light coat over the entire surface of the mount, lay the tracing paper in position and stretch into contact with the board as in tipping. If air bubbles occur force them out by rubbing from the center of the drawing out, laying a piece of clean paper over the drawing to protect it.

Mounting on Cloth.

It is sometimes necessary to mount drawings or maps on cloth. The following methods are used:

Hot mounting is best for both heavy and thin paper. For heavy paper, tack down mounting cloth with another cloth under, put 1/2 pint library paste with 1/2 oz. water in pan and bring to boil. With broad brush paste back of drawing or print quickly, working from center out, turn over and place on cloth. Have hot iron ready and iron print from center out, in circular motion, ironing fast until edges are stuck, then removing tacks to release the steam and ironing till dry. Never iron on the back, as the steam formed will cause blisters.

Cold paste may be used for hurry work, applying it to the cloth instead of the paper, and ironing as before.

For mounting thin paper. The print to be mounted is rolled, face in, on a large roller (a roll of detail paper may be used), hot paste applied starting at end, the print rolled off on the cloth, and followed up as fast as unrolled by hot irons. If cold paste is used apply it to the cloth. Never attempt to apply cold paste on thin paper.

Cold Mounting. When hot irons are not available, prints may be mounted by stretching cloth tightly on table, applying paste, and rolling with photographic print roller, leaving the cloth stretched until perfectly dry.

Methods of Copying Drawings.

Drawings are often copied on opaque paper by laying the drawing over the paper and pricking through with a needle point, turning the upper sheet back frequently and connecting the points. Prickers may be purchased, or may be made easily by forcing a fine needle into a soft wood handle. They may be used to advantage also in accurate drawing, in transferring measurements from scale to paper.

Transfer by Rubbing.

This method is used extensively by architects, and may be used to good advantage in transferring any kind of sketch or design to the paper on which it is to be rendered.

The original is made on any paper, and may be worked over, changed, and marked up until the design is satisfactory. Lay a piece of tracing paper over the original and trace the outline carefully. Turn the tracing over and retrace the outline just as carefully on the other side, using a medium soft pencil (perhaps H or 2H) with a *sharp* point. Turn back to first position and tack down smoothly over the paper on which the drawing is to be made, registering the tracing to proper position by center or reference lines on both tracing and drawing. Now transfer the drawing by rubbing the tracing with the rounded edge of a knife handle or other instrument (a smooth-edged coin held between thumb and forefinger and scraped back and forth is commonly used), holding a small piece of tracing cloth with smooth side up between the rubbing instrument and the paper, to protect the paper. Do not rub too hard, and be sure that neither the cloth nor paper move while rubbing.

Very delicate drawings can be copied with great accuracy in this manner.

If the drawing is symmetrical about any axis the reversed tracing need not be made, but the rubbing can be made from the first tracing by reversing it about the axis of symmetry.

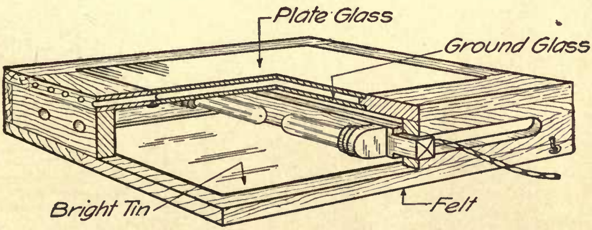


FIG. 448.—A transparent drawing board.

Several rubbings can be made from one tracing, and when the same figure or detail must be repeated several times on a drawing much time can be saved by drawing it on tracing paper and rubbing it in the several positions.

A Transparent Drawing Board.

A successful device for copying drawings on opaque paper is illustrated in Fig. 448. A wide frame of white pine carrying a piece of plate glass set flush with the top, is hinged to a base lined with bright tin. A sliding bar carries two show-case lamps, whose light may thus be concentrated under any part of the drawing. Ventilation and protection from overheating is provided by the ground glass and air space between it and the plate glass.

The frame has a piece of felt glued on the bottom and may be used on the top of any table where connection with an electric light outlet is convenient.

Drawings even in pencil may be copied readily on the heaviest paper or Bristol-board by the use of this device.

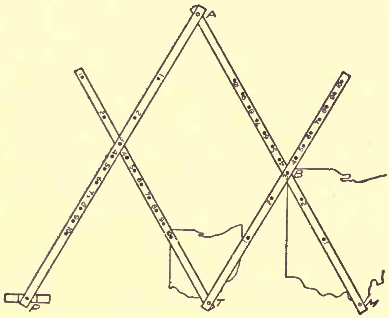


FIG. 449.—Pantograph.

The Pantograph.

The principle of the pantograph, used for reducing or enlarging drawings in any proportion, is well known. Its use is often of great advantage. It consists essentially of four bars, which for any setting must form a parallelogram, and have the pivot,

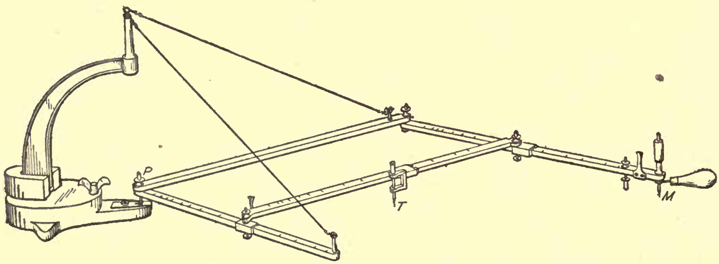


FIG. 450.—Suspended pantograph.

tracing point, and marking point in a straight line; and any arrangement of four arms conforming to this requirement will work in true proportion. Referring to Fig. 449 the scale of enlargement is PM/PT or AM/AB. For corresponding reduction the tracing point and marking point are exchanged.

The inexpensive wooden form of Fig. 449 is sufficiently accurate for ordinary outlining. A suspended pantograph with metal arms, for accurate engineering work, is shown in Fig. 450.

Drawings may be copied to reduced or enlarged scale by using the proportional dividers.

The well-known method of proportional squares is often used for reduction and enlargement. The drawing to be copied is ruled in squares of convenient size, or, if it is undesirable to mark on the drawing, a sheet of ruled tracing cloth or celluloid is laid over it, and the copy made freehand on the paper, which has been ruled in corresponding squares, larger or smaller, Fig. 451.

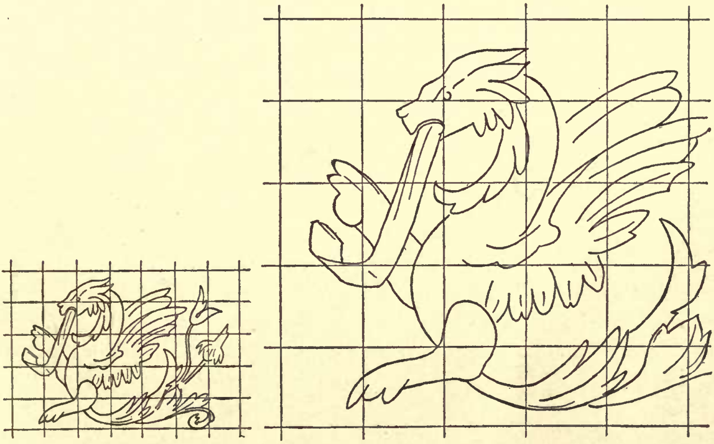


Fig. 451.—Enlargement by squares.

About Tracings.

Sometimes it is desired to add an extra view, or a title, to a print without putting it on the tracing. This may be done by drawing the desired additions on another piece of cloth of the same size as the original, and printing the two tracings together.

A figure may be taken out of a tracing, and another inserted by making an "inlay," laying the new piece under the tracing and cutting through both together with a sharp knife, then fastening the new piece in the hole with collodion.

Do not take up a blot with a blotter, but scoop it up with the finger, leaving a smear. Erase the smear when dry, with a pencil eraser.

To prevent smearing in cleaning, titles if printed from type on tracing cloth should be printed in an ink not affected by benzine. Local printers are often unable to meet this requirement, but there are firms which make a specialty of this kind of printing.

Preserving Drawings.

A drawing, tracing, or blue print which is to be handled much may be varnished with a thin coat of white shellac.

Prints made on sensitized cloth will withstand hard usage.

A method of imbedding drawings in sheet celluloid, making them water- and grease-proof, is carried on by the Dodge Motor Map Co., N. Y. The cost is about fifty cents a square foot.

Blue prints for shop use are often mounted for preservation and convenience, by pasting on tar board or heavy press board and coating with white shellac or Damar varnish. A coat of white glue under the varnish will aid still further in making the drawings washable.

Tracings to which more or less frequent reference will be made should be filed flat in shallow drawers. Sets of drawings preserved only for record are often kept in tin tubes numbered and filed systematically. A pasteboard tube with screw cover is also made for this purpose. It is lighter than tin and withstands fire and water even better.

Fireproof storage vaults should always be provided in connection with drafting rooms.

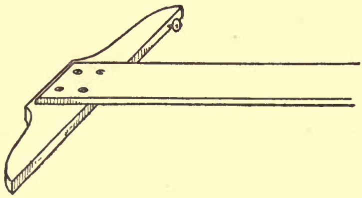


Fig. 452.

Miscellaneous hints.

A temporary adjustment of a T-square may be made by putting a thumb tack in the head, Fig. 452.

A homemade ellipsograph has been made on the principle of the pin-and-string method of Fig. 90 by adding a clip to the compass pen to hold the string, which will pull the leg in as the compass, with its center at O, moves from B to D.

If much ruling in red ink is done, a pen for the purpose with nickel plated or german silver blades is advisable.

A steel edge to a drawing board is made of an angle iron planed straight and set flush with the edge. With this edge and a steel T-square very accurate plotting may be done. These are often used in bridge offices.

CHAPTER XV.

Bibliography of Allied Subjects.

The present book has been written as a general treatise on the language of Engineering Drawing. The following short classified list of books is given both to supplement this book, whose scope permitted only the mention or brief explanation of some subjects, and as an aid to those who might desire the recommendation of a book on some branch of drawing or engineering.

Architectural Drawing.

Ware, Wm. R.—The American Vignola. 2 v. 9 1/2x12 1/2. Scranton, 1906.

Part I, The Five Orders. 76 pp., 18 pl. $2.50.

Part II, Arches and Vaults, Roofs and Domes, Doors and Windows, Walls and Ceilings, Steps and Staircases. 50 pp., 19 pl. $2.50.

Simple proportions for drawing the classic orders; and their application in composition.
A book every architectural draftsman should have.

Martin, Clarence A.—Details of Building Construction. 33 pl. 9 1/2x12 1/2. $2.00. Bates & Guild, 1905.

Suggestive details of domestic architecture representing good practice, principally in wood, as windows, cornices, etc.

Snyder, Frank M.—Building Details. Issued in parts of 10 pl. each, 16x22. $2.25 net. N. Y., 1906........

Selections of fully dimensioned details, principally of large buildings, from the drawings of various representative architects.

Descriptive Geometry.

Church, Albert E.—Elements of Descriptive Geometry. 286 pp., 6x8 1/2 rev. ed. $2.25 net. American Book Co., 1911.

This book has been a standard ever since its original publication in 1864. The present revision is by Geo. M. Bartlett.

Anthony and Ashley.—Descriptive Geometry. 134 pp., 34 pl., obl. 6x7 1/2. $2.00. D. C. Heath & Co., 1909.

A comprehensive elementary treatise.

MacCord, C. W.—Elements of Descriptive Geometry. 248 pp., 6x9. $3.00. Wiley, 1902.

Particularly good on auxiliary planes and warped surfaces.

Gears and Gearing.

Logue, Charles H.—American Machinist Gear Book, 348 pp., 6x9. $2.50. McGraw-Hill, 1910.

"Simplified tables and formulas for designing, and practical points in cutting all commercial types of gears."

Grant, George B.—A Treatise on Gear Wheels, 103 pp., 6x9. Phila. Gear Works, 1906.

A practical book on the designing and cutting of gears.

Anthony, G. C.—The Essentials of Gearing. 84 pp., 15 folding pl., obl. 6x7 1/2. $1.50. D. C. Heath & Co., 1897.

An elementary text-book on the drawing of tooth outlines.

Stutz, Charles C.—Formulas in Gearing. 6x9, 5th ed., 183 pp., $2.00. Brown and Sharpe Mfg. Co., 1907.

Useful formulas for gear design.

Handbooks.

A great many "pocket size" handbooks, with tables, formulas, and information are published for the different branches of the engineering profession, and draftsmen keep the ones pertaining to their particular line at hand for ready reference. Attention is called, however, to the danger of using handbook formulas and figures without understanding the principles upon which they are based. "Handbook designer" is a term of reproach applied not without reason to one who depends wholly upon these aids without knowing their theory or limitations.

Among the best known of these reference books are the following:

American Civil Engineers' Pocketbook, Mansfield Merriman, ed. in chief. 1380 pp. $5.00 net. Wiley, 1911.

A new book by a corps of well-known engineers.

American Machinists' Handbook, and Dictionary of Shop Terms, by F. H. Colvin and Frank A Stanley. 513 pp. $3.00 net. McGraw-Hill, 1908.

"A reference book on machine-shop and drawing-room data, methods and definitions."

Architects' and Builders' Pocketbook, F. E. Kidder. 15th ed., 1661 pp. $5.00. Wiley, 1908.

The standard architects' reference book.

Cambria Steel.—A Handbook of Information Relating to Structural Steel Manufactured by the Cambria Steel Co. 468 pp. $1.00. Phila., 1907.

A standard book for structural steel designers.

Carnegie.—Pocket Companion containing Useful Information and Tables appertaining to the Use of Steel as manufactured by the Carnegie Steel Co. 345 pp. $2.00. Pittsburg, 1903.

Catalogue of Bethlehem Structural Shapes, Manufactured by Bethlehem Steel Co. 72 pp. Bethlehem, Pa., 1909.

Contains tables for shapes rolled by this company.

Civil Engineers' Pocketbook, J. C. Trautwine. 19th ed., 1257 pp. $5.00 net. Trautwine Co., Phila., 1909.

The best known reference book for civil engineers.

Electrical Engineers' Pocketbook. H. A. Foster, ed., 1599 pp. $5.00. D. Van Nostrand, N. Y., 1908.

"A handbook of useful data for electricians and electrical engineers."

Handbook of Cost Data. H. P. Gillette. 1841 pp. $5.00. Myron C. Clark, Chicago, 1910.

For civil engineers and contractors.

Mechanical Engineers' Pocketbook. Wm. Kent. 8th ed., 1461 pp. $5.00 net. Wiley, 1910.

"A reference book of rules, tables, data, and formulæ, for the use of engineers, mechanics, and students." Universally known by mechanical engineers.

Mechanical Engineers' Reference Book. H. H. Suplee. 3rd ed., 922 pp. $5.00 net. J. B. Lippincott, Phila., 1907.

"A handbook of tables, formulas, and methods for engineers, students, and draftsmen."

Standard Handbook for Electrical Engineers. 3rd ed., 1500 pp. $4.00 net. McGraw-Hill, 1910.

Contains a more complete theoretical treatment than Foster. Of particular value to students.

Machinery Data Sheets, 6x9 "Machinery" N. Y.

A series of data sheets for designers, published as supplements to the periodical. Back numbers cut and bound may be purchased.

Lettering.

French (Thos. E.) and Meiklejohn, (R).—The Essentials of Lettering. 3d ed., 76 pp., 6x9. $1.00. McGraw-Hill, 1911.

"A manual for students and designers."

Reinhardt, Chas. W.—Lettering for Draftsmen, Engineers, and Students. 23 pp., 8 pl., 8x11. $1.00 net. D. Van Nostrand, 1895.

A complete analysis of the single-stroke "Reinhardt" letter.

Machine Drawing and Design.

A great many text-books and reference books have been written on machine drawing and designing. A few only are noted here.

Unwin, William C.—Elements of Machine Design.

Part I, General principles, fastenings and transmission machinery, new ed., 531 pp., 5 1/2x8 1/2. $2.50. Longmans, Green & Co., 1909.

Part II, Engine details 431 pp., 5x7. $2.00. Longmans, Green & Co., 1902.

A standard English text-book widely used in this country.

Spooner, Henry J.—Machine Design, Construction, and Drawing. 691 pp., 5 1/2x8 1/2. $3.50 net. Longmans, Green & Co., 1910.

Another English text-book conforming to modern English engineering practice.

Cathcart, W. E. L.—Machine Design.

Part I, Fastenings, 6x9 1/2, 291 pp. $3.00 net. Van Nostrand, 1903.

A good reference book giving modern American data from best practice.

Kimball and Barr.—Elements of Machine Design. 446 pp., 6x9. $3.00. Wiley, 1909.

A text-book with discussion of the fundamental principles of design.

Reid (John S.) and Reid (David).—A Text-book of Mechanical drawing and Elementary Machine Design. 439 pp., 6x9. $3.00. Wiley, 1910.

Contains an interesting summary of an investigation into present practice in drafting-room conventions and methods.

Jepson, George.—Cams and the Principles of their Construction. 59 pp., 6x9. $1.50 net. Van Nostrand, 1905.

A short discussion of various forms of cams and the methods of drawing them.

Mechanism.

Robinson, S. W.—Principles of Mechanism. A Treatise on the Modification of Motion by means of the Elementary Combina-

tions of Mechanism, or of the Parts of Machines. 309 pp., 6x9. $3.00. Wiley, 1900.

The authority on non-circular gearing. Treatment mainly by graphics instead of analysis.

Barr, John H.—Kinematics of Machinery. 2nd ed., 264 pp., 6x9. $2.50. Wiley, 1911.

"A brief treatise on constrained motion of machine elements." (Revised by Edgar H. Wood.)

Dunkerley, S.—Mechanism. 2nd ed., 448 pp., 6x9. $3.00. Longmans, Green & Co., 1907.

A modern text-book on the kinematics of machines, used in English colleges.

Perspective.

Ware, Wm. R.—Modern Perspective, a Treatise upon the Principles and Practice of Plane and Cylindrical Perspective, 6th ed., 336 pp., 5x7 1/2 and atlas of plates. $4.00. MacMillan, 1900.

An exhaustive work.

Longfellow, Wm. P. P.—Applied Perspective for Architects and Painters. 8x11, 95 pp., 33 pl. $2.50 net. Houghton, Mifflin & Co., 1901.

A practical book on architectural perspective.

Fuchs, Otto.—Handbook on Linear Perspective, Shadows and Reflections. 8x10, 34 pp., 13 folding pl. $1.00 Ginn & Co., 1902.

An elementary presentation in problem form, for artists and architects.

Wilson, Victor T.—Freehand Perspective. 5 1/2x9, 257 pp. $2.50. Wiley, 1900.

A thorough discussion of the principles and their application in freehand sketching.

Mathewson, Frank E.—Perspective Sketching from Working Drawings. 5x8, 77 pp. $1.00. The Taylor-Holden Co., 1908.

A good elementary book on freehand perspective.

Frederick, Frank Forrest.—Simplified Mechanical Perspective, 54 pp., 7x10, 75 cents. The Manual Arts Press, 1909.

An elementary explanation of linear perspective.

Rendering.

Maginnis, Charles D.—Pen Drawing. An Illustrated Treatise. 130 pp., 5x7 1/2. $1.00 net. Bates & Guild, 1904.

By a well-known architect. Should be in the library of every architectural draftsman.

Frederick, Frank F.—The Wash Method of Handling Water Color. 16 pp., 7x10. 50 cents. Manual Arts Press, 1908.

A helpful little guide in the use of water color.

Shades and Shadows.

McGoodwin, Henry.—Architectural Shades and Shadows. 118 pp., 9 1/2x12. $3.00. Bates & Guild, 1904.

The principles of casting shadows, and their application on architectural forms.

Sheet Metal.

Kittredge, Geo. W.—The New Metal Worker Pattern Book. 429 pp., 9x11 1/2. $5.00. David Williams, N. Y., 1911.

An exhaustive treatise on the principles and practice of pattern cutting as applied to sheet metal work.

Stereotomy.

French (A. W.) and Ives (H. C.).—Stereotomy. 119 pp., 21 folding pl., 6x9. $2.50. Wiley, 1902.

Contains practical examples of the application of stone cutting in architectural and engineering structures.

Warren, S. E.—Stereotomy, Problems in Stone Cutting. 126 pp., 10 folding pl., 6x9. $2.50. Wiley, 1893.

For civil engineering students.

Structural Drawing.

Morris, Clyde T.—Designing and Detailing of Simple Steel Structures. 201 pp., 6x9. $2.75. Eng. News, N. Y., 1909.

A clear and concise text for both students and practical men.

Surveying.

Johnston, J. B.—The theory and Practice of Surveying. 17th ed. Rewritten by L. S. Smith, 921 pp., 5 1/2x8. $3.50 net. Wiley, 1911.

A standard work on surveying.

Breed and Hosmer.—The Principles and Practice of Surveying. 2 v., 6x9. Wiley, 1908.

V. I, 546 pp., Plane and Topographic Surveying. $3.00.

V. II, 432 pp., Higher Surveying. $2.50.

Another standard work with very full discussion of drafting-room practice.

Tracy, John C.—Plane Surveying. 792 pp., 4x7. $3.00. Wiley, 1907.

A text-book and manual in convenient handbook form. A thorough and practical book on plane surveying.

Technic and Standards.

Follows, Geo. H.—Universal Dictionary of Mechanical Drawing, 60 pp., 8x11. $1.00. Eng. News, N. Y., 1906.

A book of proposed standards and conventions to introduce better uniformity.

Reinhardt, Charles W.—The Technic of Mechanical Drafting. 3rd ed., 42 pp., 11 pl. $1.00. Eng. News, N. Y., 1909.

A guide to good technic, particularly for drawing for reproduction, with excellent examples of work.

Topographical Drawing.

Reed, Lieut. H. A.—Topographical Drawing and Sketching, Including Applications of Photography. 2 v. in one, 140+88 pp., 26 folding pl., 9x12. $5.00. Wiley, 1890.

An exhaustive text and reference book on the subject.

Daniels, Frank T.—A Text-book of Topographical Drawing. 144 pp., 6x7 1/2. $1.50. D. C. Heath & Co., 1908.

A well arranged book on ink and color topography, with practical problems.

Wilson, H. M.—Topographic Surveying. 3rd ed., 910 pp., 6x9. $3.50. Wiley, 1908.

A complete work on topographic surveying, containing a chapter on topographical drawing.

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